THE EFFECTS OF STIMULUS-RESPONSE COMPATIBILITY ON RATE OF LEARNING AND TRANSFER OF STIMULUS CONTROL DURING SPATIAL OCCASION SETTING

by

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Introduction

All organisms respond to stimuli in their environment. An organism's survival relies heavily on its ability to respond to the stimuli most relevant to current needs. Failing to respond correctly to stimuli in the environment can lead to terrible accidents (e.g., Baker, Qiang, Rebok, & Li, 2008), loss of food (e.g., Van Orsdol, 2008), loss of mating opportunities (e.g., Frith & Frith, 1987; Marcellini, 1977; Sabath, 1981), or failed social interactions (e.g., Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). One factor that affects how and when organisms respond to stimuli in the environment is stimulus-response compatibility (Fitts & Seeger, 1953).

Stimulus-response compatibility (SRC) effects refer to the decremented or facilitated performance (i.e., response time and errors) observed as a result of congruence between the presentation of a stimulus set and the required response. For example, in a SRC task, participants may be required to make left and right responses to visually presented stimuli on a computer screen. Response times are faster, and the committed errors are fewer, when the presentation of the stimulus on the screen is on the same side (i.e., congruent) as the required response (e.g., a stimulus on the right side of the screen requiring a right side response) compared to a stimulus on the opposite (i.e., incongruent) side of the screen (e.g., a stimulus on the right side of the screen requiring a left side response). The occurrence of SRC effects is well documented (e.g., Fitts & Seeger, 1953; Fitts & Deininger, 1954) but the majority of this research has focused on how SRC affects performance (e.g., response time and errors) and neglects to investigate how SRC affects what is learned about the stimulus or how SRC affects the ability of cues to control responding in novel contexts. It stands to reason that a stimulus set that is less compatible with a response set or manipulandum, may take longer to learn about (i.e., more trials or sessions) or fail to gain control of responding (i.e., if and where to respond), to the same extent as a different, more compatible stimulus set would.

Most SRC tasks are designed as conditional learning procedures where a discriminative stimulus informs a participant that a certain response (e.g., a left- or right-side key) will be reinforced. Another conditional learning procedure, occasion setting, has recently been used to study how spatial stability and reliability influence stimulus control (e.g., Leising, Hall, Wolf, & Ruprecht, 2014; Ruprecht, Wolf, Quintana, & Leising, 2014). In a typical occasion setting procedure, the occasion setter (OS) (i.e., a conditional stimulus) modulates the relationship between another stimulus (e.g., a target) and the reinforcer. The OS (e.g., X) indicates that the other stimulus, target (A), will be followed by reinforcement (e.g., XA+), but the target alone (i.e., A-) is never reinforced (e.g., Holland, 1995). In one spatial occasion setting procedure (e.g., Leising et al., 2015; Ruprecht et al., 2014), the OS was a diffuse visual stimulus which preceded the presentation of a visual landmark (LM). The location of the correct response (i.e., to the right or left of the LM) was conditional on the combination of the OS and LM on each trial. This occasion setting procedure allowed for the evaluation of how differing stimuli (i.e., the OS and the LM) came to gain conditional control of where and when to respond.

Ruprecht et al. (2014) and Leising et al. (2015) demonstrated that training history and stimulus ambiguity (i.e., poor reliability and stability) can affect the extent to which an occasion setting stimulus can control the amount and direction of responding on previously trained and novel combination transfer test trials during a spatial occasion setting task. There are many similarities between this spatial occasion setting procedure and the procedure typically used to evaluate the effects of SRC. In their simplest form both procedures are really just conditional learning procedures where making a correct spatial response depends on the accurate interpretation of the information from a discriminative stimulus. For example, in both procedures participants are making spatial responses (e.g., left or right response keys relative to some centrally located stimulus for the SRC procedure and responses immediately to the left or right of a LM stimulus in the spatial occasion setting procedure) based on information from the discriminative stimulus, whether the discriminative stimulus is a colored square on the left or right of the screen (SRC) or a diffuse colored background (OS). Because an occasion setting procedure is already a preparation capable of investigating how stimuli come to gain conditional control of responding, it may be useful for studying how SRC affects the ability of a stimulus to gain conditional control over responding.

Stimulus-Response Compatibility

Fitts and Seeger (1953) were the first to report SRC effects. They provided evidence for the hypothesis that certain combinations of stimuli and response sets were more compatible with one another than others. In their experiments, three different stimulus sets and three different response sets were used. Experiment 1 tested whether it was the combination of compatible stimulus and response sets that produced the SRC effect and not just the characteristics of the stimulus set or the response set. Participants moved a metallic stylus to different positions based on the experimenter defined stimulus-response mapping (i.e., if this stimulus, then respond this way). There were three different stimulus sets (i.e., Sa, Sb, and Sc). Sa was a set of eight lights forming the outline of a circle, Sb was a set of four lights spaced equally as the corners of a square, and Sc was a pair of horizontally separated lights and a pair of vertically separated lights. There were also three different response sets (i.e., Ra, Rb, Rc), each of which corresponded with one of the stimulus sets (i.e., the light positions and response positions looked the same for Sa and Ra). Fitts and Seeger (1953) demonstrated that the compatibility between the stimulus set (e.g., Sb, stimuli arranged in a large square formation) and the response set (e.g., Rb, response locations arranged in a large square formation) led to faster reaction times and a higher degree of accuracy during choice tasks. Combinations that were highly compatible (e.g., Sa & Ra, Sb & Rb, Sc & Rc) produced the fastest response times, as well as the fewest errors compared to low compatibility combinations (e.g., Sa & Rb). Interestingly, the response set that produced the fewest errors with compatible response set (e.g., Sb & Rb) produced the most errors with other stimulus sets (e.g., Sc & Rb). During Experiment 2, the researchers utilized a similar procedure but extended the duration of the study to include 32 sessions of training across two and a half months to examine whether or not the SRC effects seen in Experiment 1 were long lasting or transient effects, and whether increasing the mental load of the participant would cause the least compatible combinations of stimulus and response sets to deteriorate more than compatible combinations. The increased mental demand was accomplished by adding a mental arithmetic task to the procedure from Session 27 to Session 30. During training sessions 1-27, participants made more errors across sessions, and made the most errors on the incompatible stimulus-response sets (e.g., Sa and Rc). The introduction of mental arithmetic during session 27 slowed down reaction times evenly for all groups (e.g., high compatibility, Sa & Ra; low compatibility, Sc & Rb), but only increased the amount of errors made by the low compatibility combinations of stimulus and response sets (eg., Sc & Rb etc). However, the researchers concluded that the results of the increased load manipulation were inconclusive. Fitts and Seeger (1953) demonstrated that compatible stimulus and response sets led to fewer errors and faster reaction times, and that these effects are long lasting. The experimenters also concluded that their results supported the idea that the best SRC arises from highly compatible stimulus and response sets that also agree with habits and stereotypes of the population, such as the tendency to move toward and not away from the point of stimulation.

A separate study conducted by Fitts and Deininger (1954) used a similar design and provided evidence that the selection of congruent stimuli and response sets that follow population stereotypes are more important than the individual sets of stimuli or responses. The researchers demonstrated that the fastest response times and fewest errors were produced when a spatial stimuli set (e.g., 8 lights arranged in a circular pattern) and a response set (e.g., response wheel with 8 spokes) were highly compatible (i.e., Sa & Ra) *and* maximized population stereotype agreement (e.g., respond toward stimulation instead of away). The most errors and second slowest set of response times came from the same spatial stimulus and response set with the lowest compatibility between the stimulus-response set and the population stereotype (e.g., a stimulus appearing at the top of the screen requiring a response down and to the left). Apart from providing more evidence for the importance of selecting congruent stimulus-response sets and response contingencies that follow population stereotypes, the researchers also illustrated that the higher the amount of spatial correspondence between the stimulus and response sets the greater the effects of SRC (i.e., slower response times and more errors) when then stimulus-response contingencies are incongruent with the population stereotypes.

Stimulus-Response Compatibility Research with Non-Human Species

Examples of stimulus-response compatibility effects have also been observed in several non-human animal species. For example, Courtiere, Hardouin, Burle, Vidal, and Hasbroucq (2007) demonstrated the occurrence of SRC effects in rats. In their experiment, rats were required to press and hold a lever until the sounding of a lateralized high- or low-pitched auditory cue then proceed to break the photobeam of the corresponding feeding niche depending on the stimulus-response mapping assigned to the different groups (e.g., if high tone then right feeding niche). The left versus right presentation of the sound was irrelevant to the rats solving the task but response times were slower for the condition where the side from which the auditory cue was presented did not match the response location (e.g., tone presented on right and required response to the left feeding niche).

Stimulus-response compatibility effects have also been found in Rhesus Macaque monkeys. Nakamura, Roesch, and Olsen, (2005) demonstrated SRC effects when monkeys were required to make eye saccade responses to green and red cues (e.g., green = saccade right, red = saccade left). There was considerable conflict evidenced by more errors and slower response times when the cue was presented in the opposite location of the required saccade direction.

There is also evidence of an observed SRC effect for pigeons. Urcuioli, Vu, and Proctor (2005) conducted an experiment where pigeons were required to respond to left and right response keys depending on the stimulus-response mapping (e.g., green stimulus, right response key) designated by the task. As in the human SRC research, Urcuioli et al. (2005) found that response times were faster when the colored stimulus appeared at the same location as the required response and slower responding when the stimulus presentation and the required response were incongruent.

Taken as a whole, these results demonstrate that the occurrence of SRC effects are not limited to a processing system specific to only humans and encourages comparative research.

The Simon Effect

Stimulus-response compatibility effects are robust, occur with multiple stimulus modalities (Courtiere et al, 2007, Fitts & Seeger, 1953) and a number of different species (e.g., Courtiere et al, 2007; Nakamura et al, 2005; Urcuioli et al, 2005). In previous examples the spatial position of the stimuli indicates the corrects response based on the rule for each specific stimulus-response set. However, SRC can affect choice reaction time and accuracy even when the spatial position of the stimuli is irrelevant to making the correct choice (Hommel & Lippa, 1995). When the location of the cue is irrelevant to making the correct choice (e.g., respond to the left key if the stimulus is green), the observed deficit in performance is referred to as the Simon effect (Simon, 1969; Simon & Rudell, 1967; Simon & Small, 1969). In the original experiment, Simon and Rudell (1967) had participants press a right-hand key or a left-hand key in response to auditory playback of the words “right” or “left” presented to either the right or the left ear. Reaction times were much faster when the side of the auditory stimulation matched the informational content of the stimulation (i.e., the word “right” presented to the right ear and the word “left” presented to the left ear). When the informational content of the stimulation did not match the side of the stimulus presentation there were significant delays in participant reaction time. In a follow up experiment, Simon and Rudell (1967) demonstrated that this effect was still present even when the ear to be stimulated was cued prior to the delivery of the “right” or “left” command. Similar to the conclusions of Fitts and Seeger (1953) and Fitts and Deininger (1954) that the best SRC comes from highly compatible stimulus response sets and maximized population stereotypes, Simon and Rudell (1967) concluded that there was a strong natural tendency for participants to respond toward the source of stimulation. When the source of stimulation did not match the required response, the participants had to inhibit responding in the direction of the stimulation before selecting the correct response. This conflict is what leads to slower reaction times and more errors (Simon & Rudell, 1967).

Simon (1968) conducted an experiment that confirmed that the result of faster response times obtained during earlier studies (i.e., Simon & Rudell, 1967) was not an artifact of stimulating one ear and requiring a response from the ipsilateral hand versus the contralateral hand, thus creating a shorter or longer distance for the information and corresponding response to travel. Simon accomplished this goal by utilizing a task similar to previous experiments (e.g., Simon & Rudell, 1967) where participants were required to respond correctly to the words "right" and "left" by moving a single response manipulandum (i.e., a joystick) to the right or left with one hand. Again there was a strong tendency for participants to respond toward, and not away from, the source of stimulation and a Simon effect was observed despite eliminating right and left hand responses.

Other studies (e.g., Simon, Hinrichs, & Craft, 1970; Wallace, 1971) have provided more evidence that the Simon effect can be observed regardless of the limb or hand used to make the response with auditory and visual stimuli, respectively. In both experiments, participants were required to make responses in a typical Simon task to "left" and "right" keys with corresponding (i.e., right hand on the right key and left hand on the left key) or crossed (i.e., right hand on the left key and left hand on the right key) hand position. The crossing of hands did not affect the magnitude of the observed Simon effect. Wallace (1972) expanded this result in a similar Simon task where the participants were unable to see the positions of their hands making the responses. The Simon effect was again observed for both corresponding and crossed hand positions indicating that the compatibility between the spatial position of the stimuli and location of the response key caused the effect, just as in the original research on SRC effects (e.g., Fitts & Seeger, 1953).

Similar to the SRC research, there is evidence of the Simon effect's resistance to training or passage of time. Simon, Craft, and Webster (1973) demonstrated a robust Simon effect utilizing high- and low-pitched tones presented to the left or right ears of participants, even after more than 1000 trials spaced across five consecutive days of training. The extended training did little to affect the differences in response times when the side of the presentation of the stimulation and the required response were incongruent, despite the spatial information (i.e., right or left ear presentation) being irrelevant to the task.

Like the research conducted by Simom et al. (1973) many of the early examinations of the Simon effect (e.g., Simon, 1968; Simon & Rudell, 1967; Simon & Small, 1969; Simon et al., 1970) focused on the compatibility between the direction or side of auditory stimulation and requiring participants to make responses to left- and right-side response keys. However, more recent research on the Simon effect has focused on the use of visually presented stimuli.

Craft and Simon (1970) were the first researchers to demonstrate the Simon effect with the use of visually presented stimuli. In their study, the researchers presented red and green lights either monocularly (i.e., to one eye) or binocularly (i.e., to both eyes) across different blocks of training to a visual field that had been divided into right and left sides. Participants were instructed to make a left-hand response to the green light and a right-hand response to the red light regardless of the eye to which the light was presented. Response times were significantly faster when the right-hand response command (i.e., the red light) was presented to the right eye and the left-hand response command (i.e., the green light) was presented to the left eye compared to the trials when the lights were presented to the opposite eye (e.g., green light to right eye). During binocular trials, response times were even faster than those obtained during the monocular trials because the spatial information could not interfere with the necessary response because the stimulus was presented to both eyes. Therefore, on monocular trials, a light presented to the eye opposite of the response side would cause conflict between the required response and the side of the stimulus presentation. However, on binocular trials there was always a stimulus on the side of the required response that eliminated the possibility for conflict between the presentation side and the response side. Craft and Simon (1970) explained that this set of results indicated that the Simon effect is due to the interference from incompatibility between the spatial presentations of the stimuli and the required response, and is not due to facilitation when the spatial presentation and required response correspond.

Hedge and Marsh (1975), Simon and Craft (1972), Simon, Small, Ziglar, and Craft (1970), and Umilta and Nicoletti (1985) have all replicated the Simon effect with stimulus color as the relevant stimulus dimension (i.e., color of stimulus directs response) as in the experiment conducted by Simon and Craft (1970). However, a number of other studies have replicated the Simon effect for visually presented stimuli, utilizing a wide array of relevant stimulus dimensions. Other relevant stimulus dimensions include the use of geometric forms (Nicoletti & Umilta, 1989; Umilta & Liotti, 1987), rotating wheels (Guiard, 1983), letters (Proctor & Lu, 1994), and vertical arrangements of stimuli paired with up or down responses (Hedge & Marsh, 1975).

Theories of Stimulus-Response Compatibility and the Simon Effect

A large proportion of research involving SRC and the Simon effect has focused on investigating why incompatibility between the location of the stimulus and the required response increases latency to respond and the number of errors committed. Whether the conflict effects are caused by relevant (e.g., SRC) or irrelevant (e.g., the Simon effect) spatial location, there is a great deal of evidence that lends support to the notion that stimulus-response compatibility effects occur because of a response-selection phenomenon (Lu & Proctor, 1995; Proctor & Reeve, 1990). There is evidence for both SRC (e.g., Hasbrouq, Guiard, & Kornblum, 1989; Spijkers, 1990) and Simon effects (Guiard, 1983; Simon & Bernbaum, 1990) occurring independently of effects caused by failures to identify the stimulus or execute a correct response. In other words, the effects are not attributed to a participant’s inability to identify stimuli in a two-choice discrimination or an inability of the participant to make a correct response.

Most proponents of the response-selection account of SRC and Simon effects believe the effects are a result of the generation of an automatic response code for the stimulus position (Umilta & Nicoletti, 1990). This response code is generated on each trial regardless of the location of the stimulus, the relevance of the location, or the response required for the task. When the response code generated by the irrelevant stimulus position corresponds with the response code generated for the relevant stimulus attribute (e.g., size, color, or shape), the response times are faster compared to trials during which the automatically generated response code for the stimulus position does not correspond with the required response based on the relevant stimulus attribute. Most research concerning response-selection accounts of the effects fall into three general categories: accounts of the orienting of attention, an account of the overlap between irrelevant dimensions of the stimulus and the response dimension, and accounts of spatial coding (Umilta & Nicoletti, 1990).

The orienting of attention account, initially proposed by Simon and Small (1969), stated that the presentation of the stimulus automatically evoked a response code in the direction of the stimulus location. This evoked response is what led to response competition between the irrelevant stimulus location and the required response based on the relevant stimulus dimension. Some research has supported this account (e.g., Mewaldt, Connely, & Simon, 1980; Verfaellie, Bowers, and Heil, 1980), but generally this account is less complete than others because Umilta and Nicoletti (1985) have demonstrated that, at least under some conditions, it is not the orienting of attention but the relative position of the stimulus presentations that lead to more errors and slower reaction times.

The dimensional overlap account, initially proposed by Kornblum, Hasbroucq, and Osman, (1990) posits that a dimensional overlap (i.e., similarity) between the response and stimulus dimensions may automatically activate a corresponding response. For example, in a standard Simon task, responses will be faster when the irrelevant stimulus dimension (i.e., location) overlaps with the relevant dimension (i.e., color of the stimulus) because the response that corresponds to the irrelevant location of the stimulus is automatically activated. However, if the automatic response corresponding to the location of the stimulus conflicts with the response indicated by the relevant stimulus dimension (e.g., size, shape, color) responding will be slower and less accurate. This account places more emphasis on the absolute location of the stimuli and responses compared to the spatial coding account that argues that the coding of the relative stimulus positions and response locations is sufficient for explaining the Simon effect.

The spatial coding account of response-selection has a considerable amount of support from both the Simon effect (e.g., Umilta & Nicoletti, 1985; Wallace, 1971) and SRC (Nicoletti, Anzola, Luppino, Rizzolati, & Umilta, 1982) literature. This account states that a spatial stimulus code (i.e., the location of the stimulus) and a separate response code (i.e., the required response for the relevant stimulus dimension) are selected during a typical Simon or SRC task. When the spatial stimulus code and response code possess conflicting information, response times are slower than when the stimulus information is congruent.

Craft and Simon (1970) provided more evidence for the spatial coding account with their second experiment. They demonstrated that a Simon effect did not occur when the eye receiving stimulation varied (i.e., right or left eye only, monocularly) but the perceived location of the stimulus did not. This supported the hypothesis that the relative, not absolute (i.e., right or left eye), spatial coding of the stimuli and responses sufficiently explained the observation of the Simon effect. If the relative spatial coding of response-selection is at the heart of the occurrence of the Simon effect, then this result is expected because presenting the stimulus to only one eye made the formation of left or right spatial codes impossible (Lu & Proctor, 1995).

Other research has supported the importance of spatial-coding for the presentation of the stimuli but also reemphasized the importance of spatial-coding for the response set. Participants in these studies were required to make left or right responses with crossed or uncrossed hands. Requiring the participants to make a left-key response with the right hand did not affect the magnitude of the Simon effect (Simon, Hinrichs, & Craft, 1970; Wallace, 1971; Wallace, 1972). Regardless of the hand making the response, the response was still coded as left or right based on the key pressed, not the hand used, indicating the importance of left and right spatial coding. These results led Wallace (1972) to conclude that, in order for the Simon effect to be observed, the stimuli and responses must both be spatially coded and that the absolute location (i.e., left or right) is less important for the development of compatibility effects.

This conclusion was supported by research conducted by Hommel (1993b) requiring participants to respond to right and left keys with differing goal actions. After hearing a high- or low-pitch auditory cue, participants were instructed to either press the correct key, or press the key that would illuminate the correct light. When the key-light mapping was inverted (i.e., right key illuminated the left-side light and left key illuminated the right-side light) and participants were instructed to produce the correct light, faster response times and fewer errors were observed when correct light was on the same side as the presentation of the tone (e.g., a low-tone, indicating a left key press for illumination of right-side light, presented on the right). Riggio, Gawryszewski, and Umilta, (1986) found a similar result with participants using crossed sticks (i.e., the right hand stick makes a response to the left key) that demonstrated that compatibility or incompatibility of stimulus and response sets depended on the relationship between the stimulus and the action goal (e.g., the tip of the stick, not the hand using the stick).

More evidence for the spatial coding of response-selection comes from the research conducted by Hedge and Marsh (1975). In their study different color response keys (e.g., green and red) were still coded spatially (i.e., left or right) even if the instructions for responding were based on the color relationship between the stimulus and the response keys (i.e., green stimulus = green key and red stimulus = red key). Other examples of non-spatial responses (i.e., those responses that are not defined by their spatial location), that still have a spatial element, support the necessity of spatial-coding of response-selection (e.g., left or right) for the Simon effect to occur (Brebner, 1979; De Jong, Liang, & Lauber, 1994; Hasbroucq & Guiard, 1991; Hedge & Marsh, 1975; Lu & Proctor, 1994; Simon, Sly, & Vilapakkam, 1981).

There is also evidence supporting the idea that development of spatial codes is sensitive to the point of participant fixation. Umilta and Nicoletti (1985) and Umilta and Liotti (1987), demonstrated that relative position of the stimulus is more crucial for the occurrence of the Simon effect than the hemispace to which the stimulus is presented. In these studies, the researchers observed a Simon effect dependent on the point of relative fixation by the participant, despite the point of fixation changing across trials, the obvious separation of the stimulus display into left and right sides, or the use of pre-cueing stimuli. This indicated that the spatial arrangements of stimuli in a visual presentation play a crucial role in the production of SRC and Simon based effects.

Each of the previous theories make an attempt to explain the compatibility effects found in SRC and Simon tasks. However, the orienting of attention account originally proposed by Simon and Small (1969) is incomplete and more research (e.g., Umilta & Nicoletti,1985) has demonstrated that in at least some instances compatibility effects can be better explained by the coding of the relative spatial positioning of stimuli. The dimensional overlap account (Kornblum, Hasbroucq, & Osman, 1990) posits that the overlap between the irrelevant stimulus dimension (e.g., spatial position) and the response required by the relevant dimension (e.g., color) is the cause of compatibility effects but also places too much emphasis on the absolute location (e.g., left or right side of screen) of stimuli. The spatial coding account is the most complete, and supported theory regarding mechanism behind compatibility effects for both SRC and Simon effects. This theory acknowledges that an automatic spatial response code is generated when a stimulus appears but also emphasizes the spatial coding of responses as well. Most importantly this theory proposes that the relative spatial position of stimuli is sufficient in explaining compatibility effects and strongly supported by the research (e.g., Umilta & Nicoletti, 1985; Hommel, 1993b).

A majority of the previously explained experiments used to study SRC effects are occasion setting procedures, some of which have spatial components. In the most basic occasion setting preparation, one stimulus (e.g., “Best Burger in Town” sign), often referred to as a conditional cue or occasion setter, is thought to modulate the relationship between another stimulus (e.g., a diner) and the reward (e.g., good food). The first stimulus sets the occasion for the second stimulus to be followed by reinforcement in an “if, then” conditional relationship. These stimuli can also inform a participant about where to respond. In many of the previously mentioned experiments, different cues, (e.g., a green circle and a red square) set the occasion for different discriminative stimuli, the letters “Q” and “P” on the keyboard or “right” and “left” with a joystick to be the correct response during a given situation.

Background on Occasion Setting

Occasion setting procedures include two basic types of trials. A trial type (XA+), where the OS X precedes target A and the opportunity for reinforcement, and a target alone trial type (A-), where the target is presented without the OS and never followed by reinforcement. This basic procedure has been successful in demonstrating occasion setting with a variety of species, including pigeons (Leising et al., 2015), humans (Ruprecht et al., 2014), and rats (Holland, 1983).

Regardless of the species, an occasion setting stimulus is usually considered to possess unique properties in regards to its relationship with other stimuli (i.e., orthogonality to the US, resistance to extinction, selective transfer). Research suggests that OSs derive their modulatory ability independently of a direct link to the US (i.e., orthogonality) and instead modulate the CS-US relationship (e.g., Schmajuk & Holland, 1998; Bonardi & Jennings, 2009; Rescorla, 1986). Because of this orthogonal relationship with the US, the modulatory properties of an OS are resistant to the effects of extinction training. If the OS (e.g. X) developed a direct link to the reinforcer during training (e.g., XA+) then extinction training (e.g., X-) would decrease the amount of responding on the originally trained trial types (e.g., XA). This idea has been supported by research demonstrating that following OS extinction training (e.g., X-), the OS is still able to modulate responding during the occasion setting trial type (e.g., XA) (Holland, 1995).

Along with orthogonality and resistance to extinction OSs usually display selective transfer of their modulatory abilities. Generally, an OS demonstrates selective transfer based on two main factors, training history and the extent to which an organism generalizes between different stimuli. For example, if OS X disambiguated (i.e., informed subject about whether or not to respond) to A during training it is likely to display more conditional control over responding to another target (i.e., target B) if target B was also disambiguated by an OS during training (e.g., Swartzentruber, 1995; Schmajuk & Holland, 1998) and if a fair amount of generalization occurs between B and A, the stimulus originally paired with OS X (Bonardi, 1996). Generalization can be expected to occur when stimuli have similar training histories, or when the physical properties (e.g., color, size, shape, intensity) between the stimuli are similar. There has also been evidence for specific transfer during a spatial occasion setting task. Cleland, Ruprecht, Lee, and Leising (2017) found that the training history of stimuli was accurate in predicting the level of transfer observed during novel transfer tests.

Recently, researchers have investigated occasion setting during a spatial search task with humans (e.g., Ruprecht, Wolf, Quintana, & Leising, 2014) and pigeons (e.g., Leising, Hall, Wolf, & Ruprecht, 2015). Ruprecht et al. (2014) trained humans on a spatial occasion setting procedure where participants were required to search for a hidden target among a row of eight response locations. Responses to the hidden target, signaled by a landmark (LM, e.g., A) were only reinforced if a colored background (e.g., X) preceded the presentation of the LM. During training, participants received occasion setting (e.g., XA+ /YB+, vs. A- /B-) training trials with the hidden target located to the left of LM B and the right of LM A. Results from novel transfer tests (XB- /YA-) indicated that the colored background gained conditional control over the amount of responding, but that more weight was given to the LM when the participant decided where to respond (Ruprecht et al., 2014). During Experiment 2, the information provided by the OS was necessary to disambiguate where to respond relative to LM A. On trials where OS X preceded LM A (i.e., XA+) the correct response was to the left of LM A, but on trials where OS Y preceded LM A (i.e., YA+) the correct response was to the right of LM A. Landmark A was made less stable (i.e., where to respond) compared to Experiment 1 because the information provided by the OS was necessary for determining the correct response. The results revealed that the colored background gained conditional control over if and where responding occurred during training, but on novel test trials the LM continued to control where responses occurred.

Ruprecht et al. (2014) also investigated how the spatial congruency between the information provided by LM and the OS would affect the amount of transfer observed during novel transfer trials (i.e., new combinations of trained OSs and LMs). During training in Experiment 2, OSs X and Y indicated the direction of the required response (left and right, respectively) relative to the shared LM A. A third OS, Z, always informed participants to respond to the left of LM B, and a separately trained LM, C, informed participants to respond to the right of LM C. These training trials allowed for novel combinations of the OSs and LMs where the spatial information provided by the cues was either congruent (e.g., YC, OS$_{\rightarrow}$ & LM$_{\rightarrow}$) or incongruent (e.g., XC, OS$_{\leftarrow}$ & LM$_{\rightarrow}$). The transfer tests revealed that participants responded more on spatially congruent transfer trials (e.g., XB, YC) than incongruent transfer trials (e.g., XC, YB), but spatial accuracy did not differ.

Leising et al. (2015) trained pigeons on an occasion–setting procedure utilizing an almost identical response array, as well as training and testing trials to Ruprecht et al. (2014). Transfer tests with pigeons indicated that the colored background gained conditional control over responding, but the LM determined where responding occurred. As in Experiment 2 from the study conducted by Ruprecht et al. (2014) with humans, the location of the hidden target relative to the LM was conditional on the colored background (X or Y) that preceded it. Transfer results indicated that the OSs gained conditional control of responding but the LM controlled where responses occurred. Following these transfer tests, Leising et al. (2015) included a post-training extinction of OS X manipulation. The post-training extinction of OS X did not affect the ability of OS X to control the amount or spatial accuracy of responding during XA test trials and demonstrated that an OS is not a generalized excitor. The results revealed control of spatial responding by the OS during transfer trials but only when the transfer LM was spatially unstable during training.

The experiments conducted with humans (Ruprecht et al. 2014) and pigeons (Leising et al., 2015) successfully demonstrated that the stability of a cue in an occasion setting task can influence the amount of conditional control over responding a cue can gain and that the level of congruency between the information provided by LMs and OSs can influence the amount of responding on novel transfer tests. The experiments also demonstrated that post-training extinction of an OS does not influence the ability of the OS to gain conditional control over a LM.

Summary and Conclusions

SRC influences performance (i.e., response time and error production) during choice discrimination tasks across a wide range of species and stimulus modalities. The similarities between a spatial occasion setting procedure and the typical procedure used to study the occurrences of SRC and Simon effects makes occasion setting an ideal procedure to investigate SRC effects. SRC effects may contribute to an OS gaining conditional control of responding during a spatial occasion setting task and subsequent transfer tests. This set of experiments investigated, via a spatial occasion setting procedure, how SRC influences the rate at which a conditional discrimination is learned, the accuracy of responding, the latency to respond, and how SRC influences whether or not a stimulus will control responding during a novel transfer situation. It was hypothesized that an OS (i.e., a conditional cue) that is part of an incongruent stimulus-response set requirement would be learned slower (i.e., more sessions), produce less accurate responding (i.e., more errors), produce longer response latencies, and would transfer less conditional control of responding (i.e., if and where to respond) during novel transfer tests than an OS that is part of a congruent stimulus-response set requirement.

The current experimental design combined a spatial occasion setting procedure with a SRC task and presented subjects with stimulus-response sets that were either congruent (i.e., respond in the direction of the stimulus presentation), incongruent (i.e., respond in the direction opposite of the stimulus presentation), or ambiguous (i.e., respond either to the right or left of the stimulus presentation). The current experiments were conducted to answer the question of how SRC influences what is learned about OSs and how SRC affects performance measures (e.g., reaction time) during an occasion setting task. The LM and OS stimuli were designed to be spatially unstable predictors of the location of the hidden goal on their own (e.g., LM-), but when both were present the spatial relationship between the two stimuli reliably predicted the location of the goal location (e.g., OS→LM). The different trial types were designed to have differing levels of compatibility with regard to the automatically generated spatial response codes and the required response for each set of stimuli. These compatibility levels were expected to influence subject performance. In Experiment 1, the LM was paired with an OS that was spatially proximal to the hidden goal and temporally overlapped with the LM. Experiments 2 and 3 addressed the limitations caused by the close proximity between the OS and hidden goal, as well as the temporal overlap between the OS and LM. In Experiment 2, the temporal overlap between the OS and LM was reduced from 12 s to 1 s. In Experiment 3, the spatial proximity of the OS to the goal was reduced by moving the OS to the edge of the response array. These manipulations were intended to weaken direct control by the individual OSs and to discourage configuration learning. We expect SRC to influence learning and performance measures during the spatial occasion setting task.

Experiment 1

There has been extensive research documenting the effects of SRC and how these effects influence performance during choice tasks (e.g., Fitts & Seeger, 1953; Simon 1969). Stimulus-response compatibility describes the fit between a stimulus or stimulus set and the required response. A compatible response matches a population stereo type (e.g., humans and non-human animals tend to respond toward the source of stimulation that predicts an appetitive unconditioned stimulus, instead of away from it). When the dimensions of the stimulus set (e.g., spatial location) match those of response set (e.g., right and left response keys) the level of compatibility between the stimulus and response sets can produce faster response times and increase response accuracy compared to an incompatible stimulus and response set. In an example of a Simon task (i.e., an SRC task where the spatial location of the stimulus is irrelevant for solving the task), a participant is required to make a right-side key press response when presented with a red stimulus and a left-side key press response when presented with a green stimulus. Stimulus-response compatibility effects come into play when, for example, the green stimulus (requiring a left side response) is presented on the right side of the screen. Because the spatial location (which is an irrelevant stimulus dimension) of the green stimulus is incompatible with the spatial location of the required left-side response the incompatibility will cause slower response times and more errors.

Most studies of SRC are concerned with performance (i.e., faster reaction times and accuracy). Consequently, participants are instructed upon, and not required to learn, the relationship required for successful choice discrimination responses during a task. Therefore, little is known about how SRC influences the way by which the stimuli are learned or how SRC (i.e., compatible or incompatible) affects the ability of stimuli to come to control responding.

There is some evidence that SRC may affect how a feature positive discrimination is learned. For example, Fitts and Seeger (1953) demonstrated that participants made more errors across sessions of training when making responses that were incompatible with the stimulus set (i.e., stimulus set A and response set C). The conflict caused by incompatibility between the stimulus and the response may result in slower learning and less weighting of the information provided by that stimulus.

Many studies of SRC employ a simple occasion setting design. Previous occasion setting research conducted by Leising et al. (2015) and Ruprecht et al. (2014) established a procedure for spatial occasion setting in which the OS provides information about where to respond in relation to a landmark (LM). With this added spatial component to an occasion setting design, there is the potential for SRC effects. Specifically, when a LM stimulus was presented on the left- or right-side of a screen or to the left or right of a fixation point, it will automatically be coded spatially. This will occur even if the position of the stimulus is uninformative for the task (Simon, 1969). Consequently, if the OS signals one kind of response, but the spatial position of the LM were to be incongruent, SRC effects might be expected. However, the OS stimuli used in the experiments conducted by Leising et al. (2015) and Ruprecht et al. (2014) were diffuse colored backgrounds that filled the entire screen. This method of presentation would complicate interpretations in terms of spatial and response codes and thus cannot inform the question regarding the possibility of SRC effects in occasion setting tasks.

One additional limitation to interpreting previous results as SRC effects has to do with information signaled by the OS and LM. In previous spatial occasion setting procedures the diffuse OS could not signal a specific direction for which to respond on its own and created no conflict between required and automatic responding. The present experiment solves both problems by replacing the diffuse OS with a discrete OS placed underneath the response array. By occupying a specific location, the OS can enter into a meaningful spatial relationship with the LM. In particular, in these experiments the location of the hidden goal in relation to the LM was dependent on the spatial position of the LM relative to the OS. For example, during an occasion setting trial (e.g., XA+ or +AX) the direction of the reinforced response was dependent on the position of A relative to the X. When A was to the right of X, then the correct response was to the right of A; whereas, on another trial when A was to the left of X, then the correct response was to the left of A (see Figure 1). From trial to trial the direction of the response was dependent on the positioning (e.g., left or right) of the OS relative to the LM. This procedure should have decreased the stability (i.e., where to respond) of OS X and increased reliance on the spatial position of the OS. This increased reliance on the OS may exaggerate any learning or performance differences at test due to SRC effects. There were three primary research questions expected to be answered with Experiment 1. The first was if participants could learn an occasion setting task and respond accurately when the location of the hidden goal was dependent on the spatial relationship between the OS and LM. The second was if differing levels of compatibility between the stimulus set and the required response would influence the speed at which an occasion setting discrimination was learned. The third was if compatibility effects would influence performance (magnitude of responding, accuracy, and response latency) and how would the effects on performance be different once the task was learned.

On Congruent trials (XA+/ +AX) the LM appeared to the left or right of the OS. Responses in the direction of A congruent with the direction that A appeared relative to X were reinforced (e.g., a response to the right of LM A was reinforced only if LM A appeared to the right of OS X). The opposite was true for Incongruent trials (Y+B, B+Y). Ambiguous trials were even more unstable, with Z occupying the same two locations relative to a LM as X and Y, but signaling a reinforced response either to the left or right of each position (e.g., LM C would appear to the right of Z but across trials would be reinforced to the left and right of C, and the same is true when C appeared to the left of Z). During test OS stimuli and LM stimuli were presented in either the same occasion setting pairing as training or one of two transfer types: direct transfer, where the OS and LM from the two stable compatibility types were switched, or ambiguous transfer where the OS stimuli from Congruent and Incongruent training trials were paired with LM C which was a less stable spatial indicator of the location of the hidden goal during training.

It is very possible that the differing spatial locations of OS and LM stimuli during the presence of the OS for the entire trial during Experiment 1 may influence the predictive value of each stimulus on its own. Each stimuli's proximity (how near the stimulus is to the goal), stability (how constant is the information provided), and reliability (how much does the stimulus disambiguate whether a response should occur) in predicting the location of the hidden goal may cause some of the individual stimuli to be treated differently than others. For example, OS Y is very proximal, as it is always underneath the goal, stable, because where it directs responding does not change across trials, and reliable, because it always indicates that reinforcement can be earned. Individual LMs are proximal, but not nearly as stable or reliable because the correct response location in relation to the LM changes across trials based on the location of the OS and LMs alone do not disambiguate whether reinforcement is available (e.g., reinforcement is never available on LM alone trials). Occasion setter X has high reliability and similar stability to the LM but is less proximal than all other stimuli. These factor should influence the predictive value of each stimulus and Bayesian spatial integration predicts that a highly variable stimulus, in terms of predicting the goal, will receive less weight than a stimulus with low predictable variability (Bayes, 1763; Cheng, Shettleworth, Huttenlocher, & Reiser, 2007). This may mean that OS Y will be treated differently, based on its predictive weight than the other stimuli, including OS X.

Similarly, the close proximity of the OS and LM stimuli and the temporal overlap of the OS and LM on occasion setting trials may have encouraged participants to learn about the stimuli as a configuration instead of independent stimulus elements. However, the current experiment is designed to temporally discourage configural learning by sequentially presenting the stimuli and requiring a response to the OS stimulus before the LM appears and spatially discourage configural learning by using discrete colored OS stimuli that are presented spatially separate from the LMs. This aspect of the experimental design does not guarantee configural learning will not occur but it is promising that similar spatial occasion setting studies report results in support of an elemental approach to learning the discrimination.

Experiment 1a: Long Duration Proximal Occasion Setting Stimulus - Pigeons

Method

Subjects

Six racing Homer pigeons (*Columbia livia*) acquired from an FDA approved breeder served as subjects. Subjects were maintained at a bodyweight between 85-90% of their free-feeding weights. Pigeons were housed individually in a colony roomed maintained under a 12-hour light-dark cycle. Pigeons had free access to water and grit. All experimental procedures were conducted during the light portion of the cycle. All eight pigeons were experimentally naïve prior to the beginning of the study. All research was conducted in accordance with approved TCU IACUC protocols (12/12; 16/01).

Apparatus

All training and testing of subjects was conducted in a flat-black Plexiglas chamber. The front wall of the chamber was composed of an LCD computer monitor (L1750, HP Palo Alto, CA) and was used to display the stimuli in the task. The monitor was lined with an infrared sensor frame (EZ-170-WAVE, ezscreen, Houston, TX) and was capable of detecting responses made to the screen. A 28-V houselight located in the center of the box's ceiling provided constant illumination. Throughout the experiment a 3-s access to mixed grain was presented by a food hopper (Coulbourn Instruments, Allentown, PA) equipped with a light located directly beneath the center of the monitor and flush with the floor of the chamber. Following the access to grain a 15-s ITI preceded the onset of the next trial.

Touchscreen stimuli

The visual stimuli used in Experiment 1a fell into one of three stimulus categories: response location, occasion setter, or landmark. The response locations were a set of eight squares that measured 2 cm^2 and were equally spaced 2.2 cm apart (center to center). The row of response locations was presented 16 cm from the bottom of the screen. The OS stimuli were presented as colored squares that measured 2 cm^2 that appeared 2.2 cm below the response locations (center to center). There were three differently colored OSs used during Experiment 1a: solid red, orange, and blue squares (see Figure 1). The three landmarks measured 2 cm^2 and were a green square with thin vertical white stripes, a yellow square with thin horizontal white stripes, and a pink square with thin diagonal white stripes. The visual stimuli presented during the experiment were programmed and executed using Visual Basic 6.0 software.

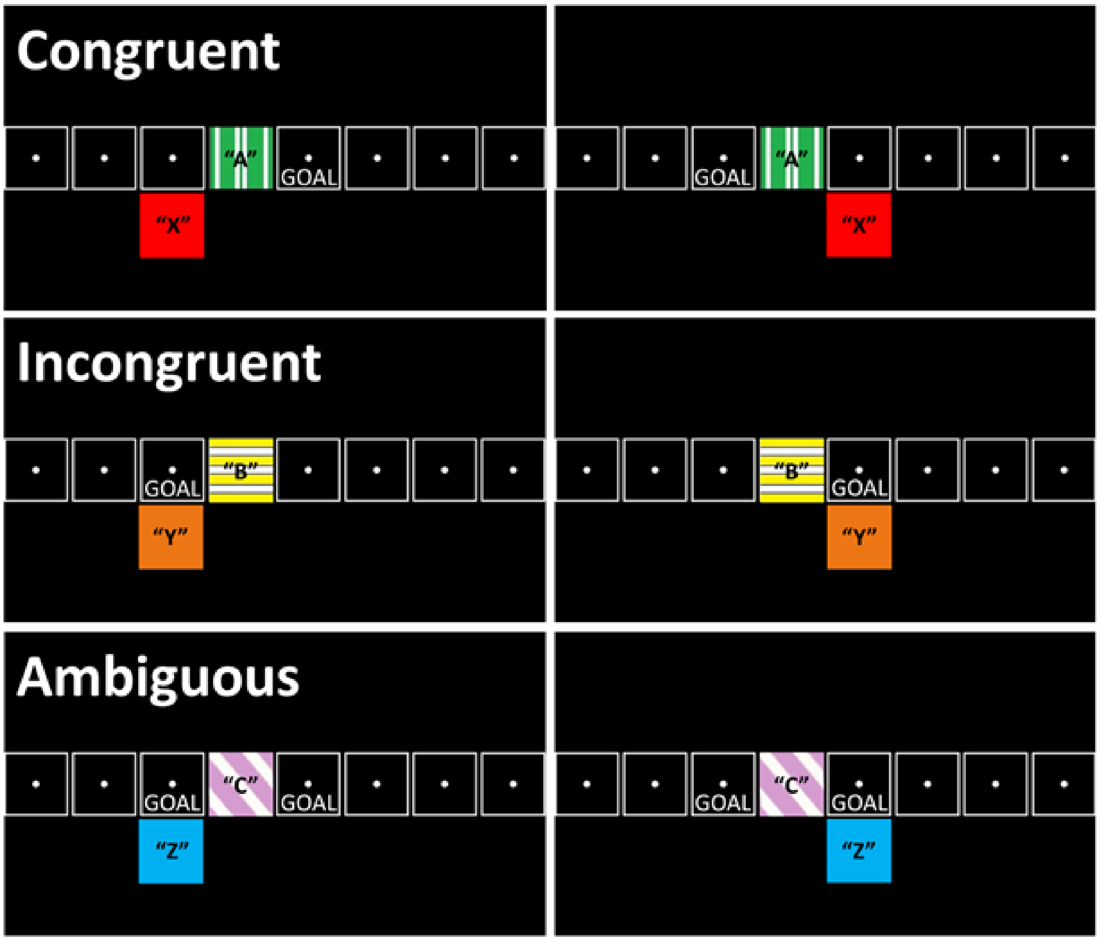


*Figure 1***.** Displays the combinations of the OSs and LMs that made up the occasions setting training trial types for Experiments 1a, 1b, and 2. The OSs were three uniquely colored squares,

X (red), Y (orange), and Z (cerulean) and the LMs were three uniquely colored and patterned squares A (green with vertical white lines), B (yellow with horizontal white lines), C (pink with diagonal white lines). The word “GOAL” in a response box indicates the location of the hidden goal on each trial type relative to the positioning of the OS and LM. When the “GOAL” is present on both sides of the LM there was 50% chance of either side hiding the goal each trial. The trial types are categorized into Congruent, Incongruent, and Ambiguous based on the response requirement (i.e., left or right of the LM). Colors of LMs and OSs were counterbalanced across subjects. LM alone trials (A-, B-, C-) are not shown.

Procedure

Pretraining.

Prior to occasion setting training, the six subjects were shaped to respond to a white circle displayed in the center of the monitor with a peck from their beak. To establish pecking, pigeons were presented with a mixed Pavlovian and instrumental procedure. After the pigeons were reliably pecking the stimulus, eight response boxes appeared during training, and were arranged in a horizontal row in the middle of the monitor. During each subsequent trial, one of the eight response boxes was selected as the goal location and was filled in white to 100% brightness and the rest of the remaining response location were filled in to 35% brightness. The brightness of the selected goal location was reduced to 35% within and across session and the responses made to the goal location were reinforced on a continuous reinforcement (CRF), Random-ratio (RR) 2, RR3 then a RR4 schedule (c.f. Leising, Sawa, Blaisdell, 2012) as subjects advanced through phases (see Table 1).

Table 1

Phase	Description	Stimuli	Stimulus Location	Schedule of Reinforcement
1	Stimulus Training	White square	Location 4 or 5	CRF
2	Stimulus Training	White square to outline of square after peck	Location 4 or 5	RR
3	Stimulus Training	White square to outline of square after peck and colored OS stimuli	Location 4 or 5 Below location 4 or 5	RR2
4	Stimulus Training	White square to outline of square after peck and colored OS stimuli	All locations All locations	RR2
5	Response Array Training	100% marked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	CRF
6	Response Array Training	80% marked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	RR2
7	Response Array Training	67% marked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	RR4
8	Response Array Training	50% marked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	RR4
9	Occasion Setting Training	Unmarked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	CRF
10	Occasion Setting Training	Unmarked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	RR2
11	Occasion Setting Training	Unmarked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	RR3
12	Occasion Setting Training	Unmarked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	RR4
13	Transfer Testing	Unmarked goal, OS and LM stimuli	LM within visible response array OS beneath visible response array	No Reinforcement

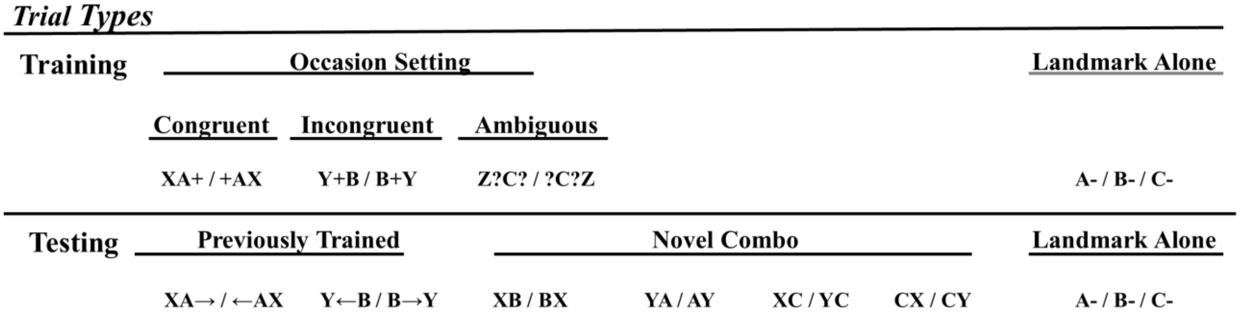
Table 1. Displays the phases of training for the pigeons from Stimulus Training to Transfer Testing. During Phases 2-4 when pigeons pecked the white square and earned reinforcement the fill disappeared and left only the white outline, to prepare the pigeons for the response array that was present on Phases 5-13. All OSs were presented below the response array and Landmarks (LM) and the illuminated goal were presented in the response array. Continuous reinforcement (CRF) was available at the beginning of the training and at all major shifts in the procedure. A random ratio (RR) schedule was used to increase pigeons responding. No reinforcement was available during the test blocks of trials during the transfer test.

Occasion setting training.

Occasion setting training consisted of nine distinct trial types, AX+, XA+, BY+, YB+, CZ+, ZC+, A-, B-, and C- (see Table 2). All occasion setting trials (e.g., X→A+) (see Figure 1) began with the appearance of an OS (X, Y, or Z) below one of the eight response locations. To standardize fixation across subjects and prepare for SRC, the subject was required to peck the OS before the LM appeared. The LM (e.g., A) appeared in one of the six response locations (the LM could not appear in location 1 or 8). On all occasion setting trials the onset of the OS preceded the onset of the LM. If no response was made to the OS, the trial ended after 120 s and the OS was removed. After the LM appeared the OS remained on the screen and overlapped temporally with the LM, for 1 s before disappearing. The LM remained on the screen for 19 s after the removal of the OS allowed the subjects to respond in the presence of the LM for the last 19 s of each trial. After an average of 63 sessions of acquisition on the occasion setting tasks, session spatial response accuracy, between 40 and 60%, indicated that pigeons were unable to learn where to respond to find the hidden goal. The following change to the procedure was implemented to help the pigeons learn where they were supposed to respond. Instead of removing the OS after a 1 s overlap the OS remained on the screen for the entire duration of the trial allowing subjects to make all responses in the presence of both the LM and the OS.

The spatial location of the OS in relation to the LM (i.e., to the left or right) indicated the correct response location on each compatibility type during training. Responses made to the hidden goal location were rewarded, until stimulus offset (i.e., it is possible that subjects received multiple reinforcements per trial), with a 3-s presentations of mixed grain followed by a 15-s inter-trial interval (ITI) prior to the beginning of the next trial.

Because the spatial location of the OS informed the subject about where to respond, each trial type (e.g., X→ A+) had two sub trial types (e.g., XA+, +AX). The notation XA+ indicates that the LM A appeared to the right of the OS X and that the correct response was the response location immediately to the right of LM A, indicating a Congruent trial type (see Figure 1 and Table 2). The notation Y+B indicates that the LM B appeared to the right of the OS Y and that the correct response is the response location immediately to the left of LM B, indicating an Incongruent trial type. Though the exact position of the LM within the array changed across trials, the spatial relationships between the stimuli and goal within each trial type did not change. For Ambiguous trial types containing OS Z and LM C (e.g., ZC+), there was always a correct hidden goal location but there was a 50% chance that the hidden goal was on the left or right side of the LM C on every trial. Occasion setter Z informed subjects that they should try to find the hidden goal but it did not reliably indicate the exact location of the hidden goal (i.e., Z+C, C+Z, ZC+, +CZ). During trials of A-, B-, C- the LM was presented alone for 20 s and responses were never reinforced.



Trial Types							
Training	**Occasion Setting**						**Landmark Alone**
	Congruent	**Incongruent**	**Ambiguous**				
	XA+ / +AX	**Y+B / B+Y**	**Z?C? / ?C?Z**				**A- / B- / C-**
Testing	**Previously Trained**		**Novel Combo**				**Landmark Alone**
	XA→ / ←AX	**Y←B / B→Y**	**XB / BX**	**YA / AY**	**XC / YC**	**CX / CY**	**A- / B- / C-**

Table 2. Displays training and testing trial types for Experiments 1a, 1b, 2, and 3. A “+” indicates a trial type where reinforcement was delivered following a correct response and also indicates the location of the hidden goal relative to the LM for a given trial type. A “?” indicates a trial type where the location of the hidden goal had a 50% chance of being on either side of the

LM. During training a “-” indicates that reinforcement was not available on that trial. During testing all trials were nonreinforced, but “→” (e.g., XA→) indicates the location of the reinforced hidden goal from training. Reinforcement was never delivered during testing of previously trained or novel combination transfer trials (bottom portion of table). Participants and subjects received only one of the two pairs of the transfer trial types utilizing LM C, either XC/YC or CX/CY.

Criterion to advance to test.

To advance to the through training phases individual subjects needed to make the correct response on 75% of the occasion setting (Congruent & Incongruent only) trials and spatial accuracy, calculated by taking the number of responses made to the hidden goal location divided by all responses, needed to be above 60% for each compatibility type. Occasion setting performance was measured as a discrimination ratio (the number of responses during occasion setting trials (e.g., XA+) compared to the number of responses during LM alone (e.g., A-) trials). As subjects moved through training phases the response requirement was increased from a continuous reinforcement schedule (CRF) where each correct response to the hidden goal was rewarded with access to grain, to a random ratio 2 (RR-2) schedule of reinforcement where each response to the hidden goal had a 50% chance of grain access, to a RR-4 schedule of reinforcement where each response to the hidden goal had a 25% chance of grain access. The brightness of the marked goal location gradually decreased down to 35% brightness (i.e., the goal location and other response locations are the same brightness) across phases. After subjects successfully reached the performance criterion across two consecutive session of training on the RR4 schedule of reinforcement they were advanced to testing.

Test.

After successfully completing the training phase of the experiment all subjects received two shuffled blocks of 13 non-reinforced test trials in the middle of a normal session of training. Subjects received two separate testing sessions separated by one session of regular training. Each testing session consisted of an equal number of reinforced (e.g., A+X) and non-reinforced (e.g., A-) trials as in the regular training sessions. Test trials fell into two categories, Previously Trained: AX, XA, BY, YB, A, B, and C and Novel Combo: BX, XB, AY, YA, and XC, YC or CX, CY (see Table 2 for trial types). The order of trial presentation was counterbalanced across subjects and the duration of the ITIs, OS stimuli, and LM stimuli and onset of the stimuli was the same as in training.

Results

Only two of the six pigeons that started the study made it to testing. Two pigeons died during training from complications unrelated to the experiment and two birds did fail to meet advancement criterion.

Behavioral Measures and Description of Data Analysis

Prior to running any analyses on the data, a two-way ANOVA was conducted to examine the effects of location (AU vs. TCU) and compatibility level (Congruent, Incongruent, & Ambiguous) on performance for each dependent variable in the experiment. Across all dependent variables there were no statistically significant interactions between location and compatibility level. All additional data analyses were conducted on the combined participant data (AU & TCU) for each of the dependent variables.

Number of responses during each test trial was used in two ways. First, the magnitude of responding was calculated by summing the total number of responses across all locations during each of the distinct trial types during training and testing to evaluate the excitatory value of each stimulus combination. Magnitude data were only analyzed for testing trial types because participants were receiving reinforcement on some trials but not others during training. Second, number of responses was used to calculate a discrimination ratio (DR) by dividing the average sum of responding during a LM on an occasion setting trial (XA+) by the average sum of responding during a LM alone trial plus responding during a LM on an occasion setting trial. The DR was used to evaluate whether the occasion setting discrimination had been learned.

Response accuracy was calculated for first response as well as all responses during trials. First response data were more informative for the investigation of SRC effects whereas all response data were informative for indication the amount spatial control displayed by the OS and LM across an extended period of time. Response accuracy data were calculated by taking the sum of responding at the correct goal location divided by the sum of responding at all other locations for each trial type during training and testing (e.g., 7 responses at goal and 3 responses to all other locations led to an accuracy proportion of .70). Response accuracy data were only calculated for trained trial types.

A spatial difference score was calculated for transfer tests. There was not a clearly defined correct goal location on transfer trials at test. Instead, each stimulus in a transfer trial predicted the goal location in a different direction based on its training history. A difference score was calculated by subtracting the sum of responses occurring at the location predicted by the LM from the sum of responses occurring at the location predicted by the OS. Positive difference scores were indicative of spatial control by the OS and negative difference scores were indicative of spatial control in the direction opposite of that predicted by the OS.

Mean latency to respond was calculated by recording the time of the first response and subtracting it from the time of the appearance of the LM on each trial. Only first response data were used to calculate response time. Response latency data were trimmed prior to a log transformation eliminating any responses that occurred faster than 150 ms or slower than 2500 ms. A typically used cut off point for reaction or response time data in the literature is 2000 ms (e.g., Simon & Sudalaimuthu, 1979). However, in most of these studies participants have their hands or fingers on response keys that correspond to one of two possible response option (e.g., yes vs. no, left vs. right). In the current procedure subjects and participants had eight possible response locations and had to move from the location of the OS stimulus beneath the response array to one of the response boxes in the array, taking more time to make a response than typical SRC studies. It is for this reason that the data were trimmed at 2500 ms. After response latency data were trimmed they were log transformed (Log 10) to reduce the skew of the data distribution. All statistical analyses were conducted on the transformed data but raw data were used for the descriptive statistics as well as the figures (Bosson, Swann, & Pennebaker, 2000; Richeson & Nussbaum, 2004).

Occasion Setting

Training.

Figure 2 displays occasion setting DRs for each pigeon across training. Training data from Phase 8 or less is not displayed because the goal location was marked on every phase prior to Phase 9 (see Table 1). Both pigeons demonstrated DRs above chance during the first block of training and DRs remained above chance for the duration of training. Drogo demonstrated a higher DR for Incongruent compared to Congruent or Ambiguous but this difference was gone by the second block of training.

Discrimination ratios for all compatibility types were compared to chance, .5, with a single-sample *t*-test. All DRs were significantly above chance by the end of the first block of training, all *ts* > 7.03, all *ps* < .001.

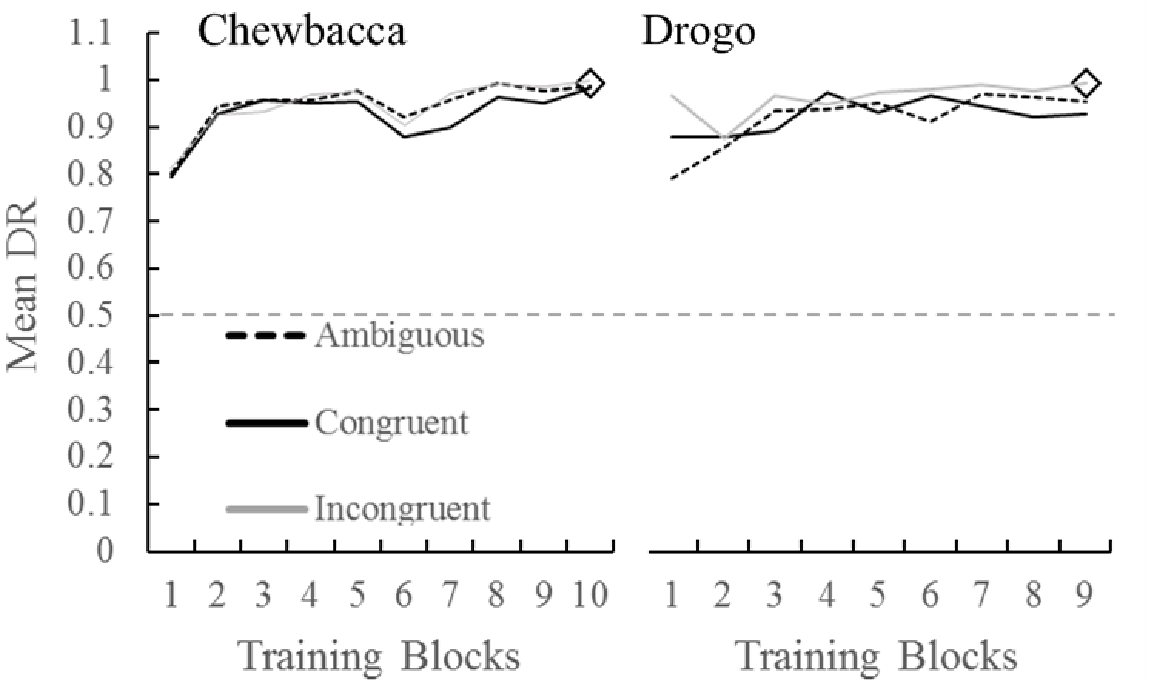


Figure 2. Mean discrimination ratio for each compatibility type and each bird during blocks of training. Discrimination ratio data for Chewbacca is displayed in the left panel and each block consisted of 21 sessions of training. Discrimination ratio data for Drogo is displayed in the right panel and each block consisted of 23 sessions of training. The black outlined diamond is the combined average DR (Congruent & Incongruent) during testing for each bird. The dotted gray line represents chance level of responding.

Testing.

We were limited in the ability to analyze DRs during test because only two birds made it to test. During testing, both pigeons displayed nearly perfect discrimination ratios for both of the trained compatibility types (Congruent & Incongruent). Chewbacca made a single response during a LM alone trial (LM B) across both days of testing. Because only two birds made it to testing, group statistics cannot be used to analyze the data. However, the DR pattern across birds was very consistent. Figure 2 displays the combined average test DR (Congruent & Incongruent) in relation to the last block of training for each bird.

Magnitude of Responding

Testing.

Figure 3 displays the average magnitude of responding for each of the stimulus types during the two sessions of testing for each bird. There was almost no responding during any of the LM alone trials during testing. Across birds there was more responding on transfer trials using OS Y than OS X during transfer test trials. There was no consistency between how much birds responded during the direct transfer trials (XB, YA); Chewbacca responded more on XB trials and Drogo responded more on YA trials. Both birds responded more on Congruent ambiguous transfer trials than on Incongruent ambiguous. Without statistical analysis it is impossible to say whether or not these differences are significant or reliable.

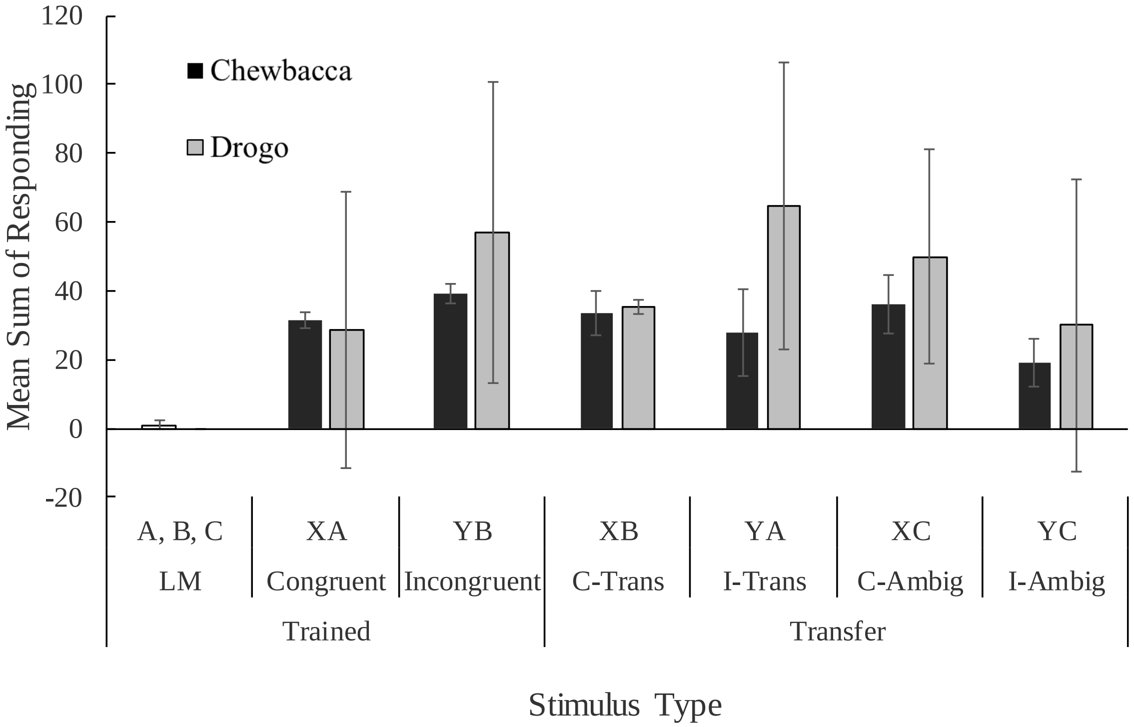


Figure 3. Magnitude of responding across the two days of testing for each bird. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled "Trained". Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled "Transfer". The letters "C" and "I" represent the OS from training used in each transfer trial and correspond to the training compatibility type that used that OS (e.g., I corresponds with Incongruent). "Trans" indicates a transfer trial where the OS LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. "Ambig" indicates a transfer trial where one of the training OSs is paired with LM C, which provided ambiguous information about the location of the hidden goal during training. Responding on LM alone trials was collapsed across trial types. Error bars represent standard deviation of the mean.

Accuracy and Difference Score

Training.

Figure 4 displays accuracy data for each pigeon across training for first responses only. Accuracy data from Phase 8 or less is not displayed because the goal location was marked on every phase prior to Phase 9 (see Table 1). Both birds displayed the highest accuracy on Incongruent trials, followed by Congruent trials, and were the least accurate on Ambiguous trials. The largest and most consistent differences between Incongruent and Congruent occurred during the first block of training. By the middle blocks of training this difference was reduced and for both birds little difference is observed in the last two blocks of training. Responding on Ambiguous trials was never above chance levels of responding.

Accuracies for each compatibility type for each bird were compared to chance, .5, with a single-sample *t*-test. During the first block for both birds, the only compatibility type that was above chance was Incongruent, $p < .05$, but both birds were significantly above chance during the middle and last block of training for both Incongruent and Congruent trial types. Birds were never above chance for the Ambiguous trial type for any block during training, $p > .05$.

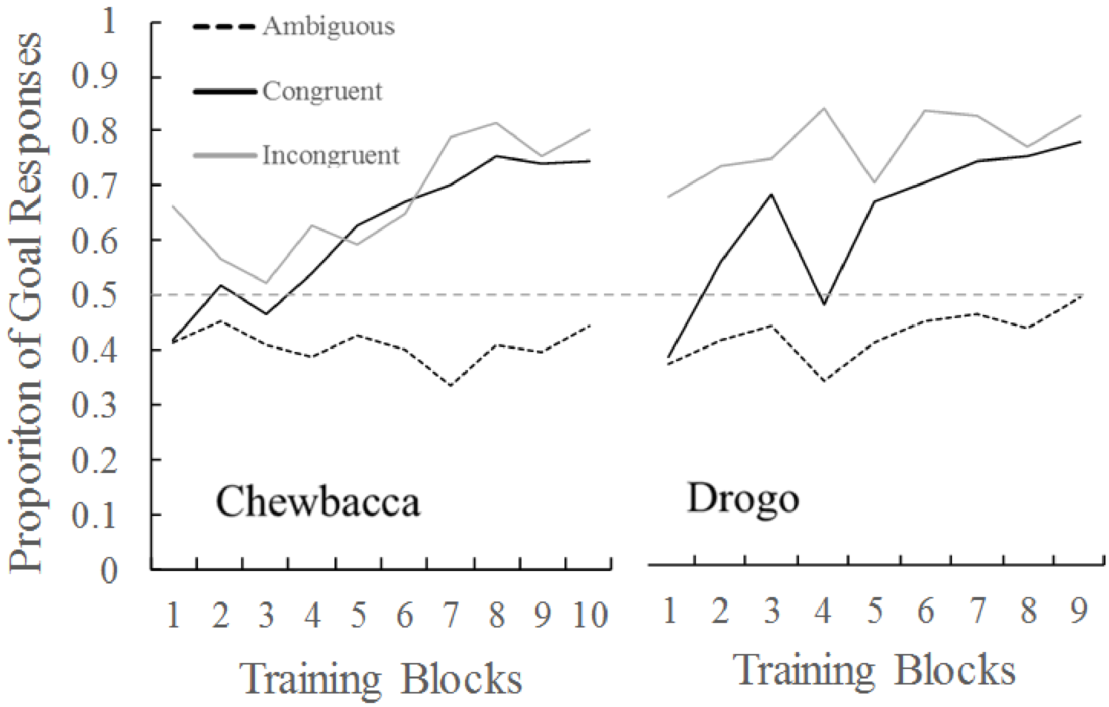


Figure 4. Mean proportion of responses occurring at the correct goal location for each compatibility type across training. Accuracy data for Chewbacca is displayed in the left panel and each block consisted of 21 sessions of training. Accuracy data for Drogo is displayed in the right panel and each block consisted of 23 sessions of training. Chance based on all eight response locations would be .125. However, we tested each compatibility type against .5 based on responding to the right or left of the LM. The dotted gray line represents this comparison. This was the case for all figures displaying proportion.

Testing.

First Response.

Figure 5 displays the average accuracy for each of the compatibility types during the two sessions of testing for each bird. The birds had the same level of accuracy across the trained compatibility types at test. Figure 5 also displays the average difference score each bird on transfer trials during the two sessions of testing. Both birds responded in the direction of OS X when paired with LM C, but there was little consistency in data from the other transfer trials at test. Without statistical analysis it is impossible to say whether or not these differences are significant or reliable.

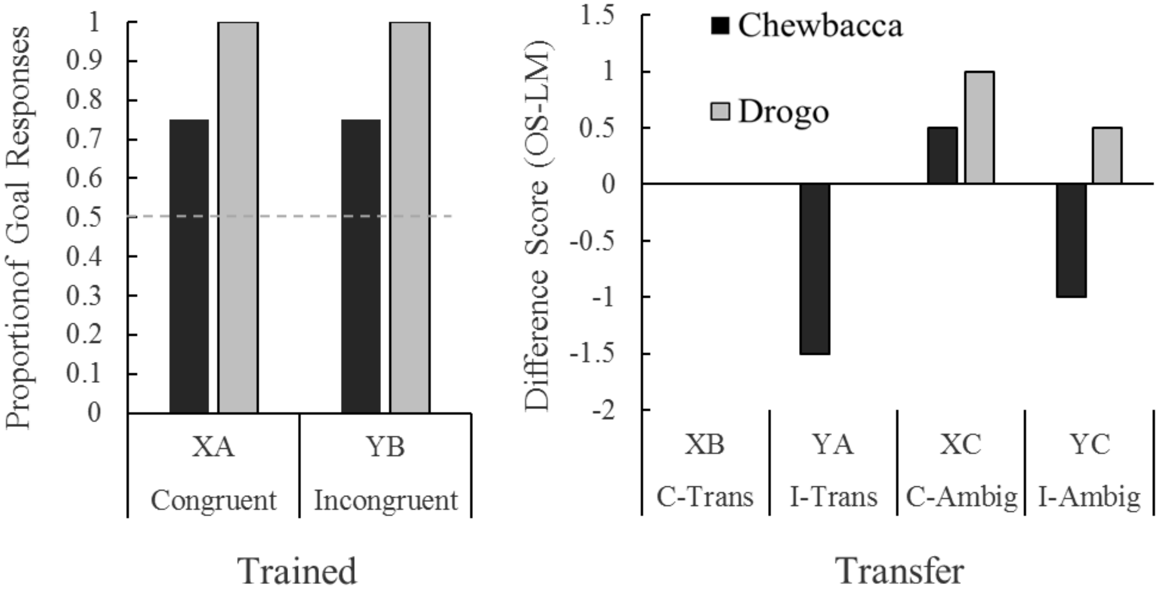


Figure 5. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for first response only. The figure displays the stimuli as well as the compatibility type during test. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type that used that OS (e.g., I corresponds with Incongruent). “Trans” indicates a transfer trial where the OS LM pair utilized the LM from the Incongruent trial and the OS from Congruent trial, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs is paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents the chance level of responding.

***All Responses*.**

Figure 6 displays the accuracy and difference scores from testing for all of the responses during test trials. Birds were consistently more accurate on the trained Incongruent trials than the trained Congruent trials. Birds also showed more consistency with one another for difference scores when all responses were included. The data indicate LM driven spatial responding on XB and YC trials, but OS driven responding on YA and XC trials. Without statistical analysis it is impossible to say whether or not these differences are significant or reliable.

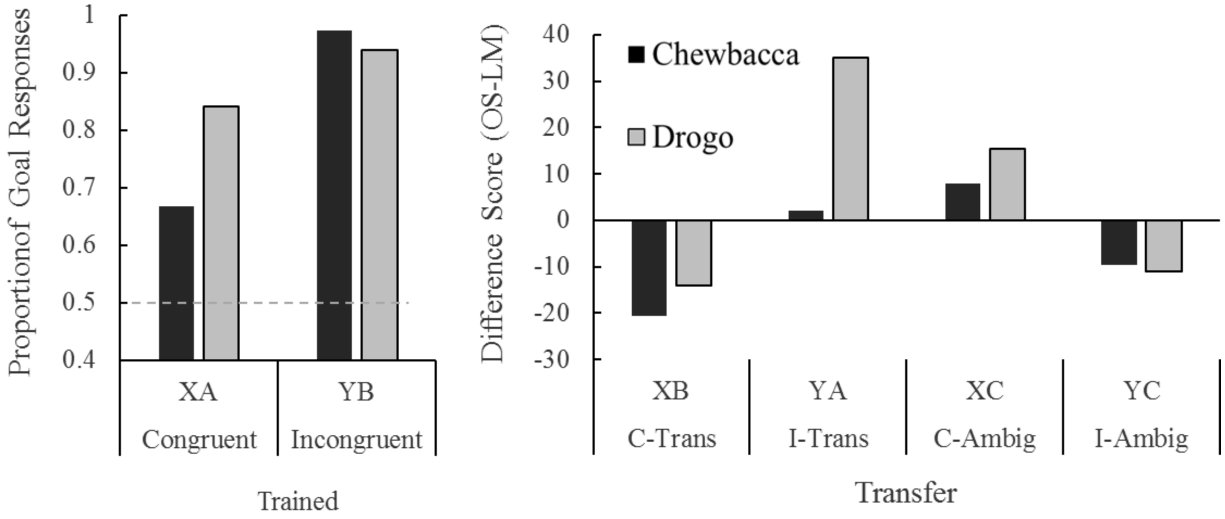


Figure 6. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the differences scores over responding as the mean difference score for all the responses at test. The figure displays the stimuli as well as the compatibility type during test. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type that used that OS (e.g., I corresponds with Incongruent). “Trans” indicates a transfer trial where the OS LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs is paired with LM C, which

provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents the chance level of responding.

Response Latency

All statistical analyses for response latency were conducted on the log transformed data (Lg10) but raw data were used for the figures and descriptive statistics.

Training.

Both pigeons demonstrated faster response latencies for Incongruent trials than Congruent or Incongruent trials, but there was no consistent difference between Congruent and Ambiguous trials. Drogo responded consistently faster on Incongruent trials across training but Chewbacca responded faster on Incongruent trials as training progressed. Figure 7 displays the raw data mean response latencies for the different compatibility types during training.

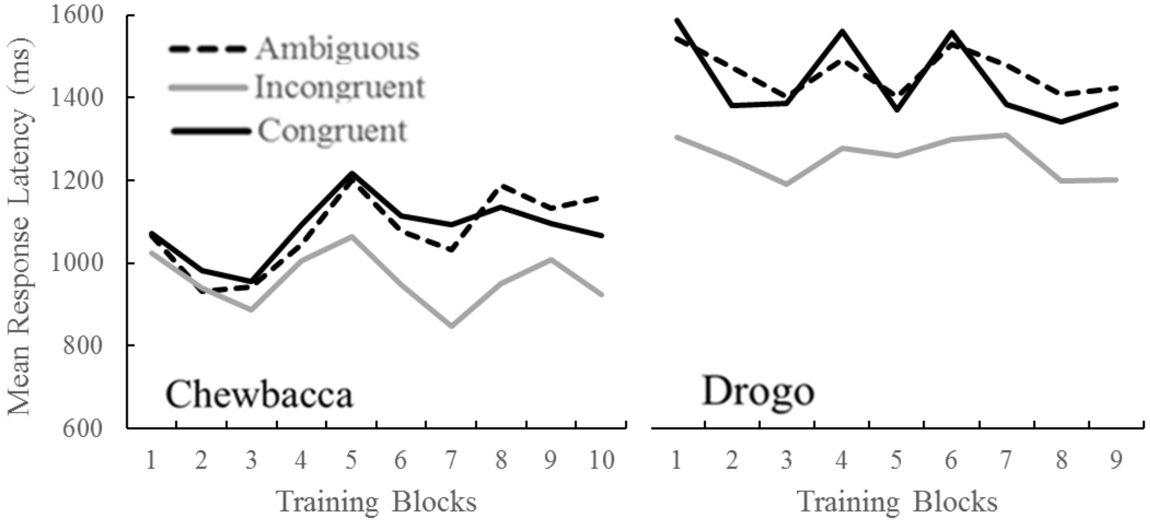


Figure 7. Mean response latency for each of the compatibility types across training. Response latency data for Chewbacca is displayed in the left panel and each block consisted of 21 sessions of training. Response latency data for Drogo is displayed in the right panel and each block consisted of 23 sessions of training.

Testing.

Figure 8 displays the average response latency for each of the compatibility types for each bird during testing. Both birds displayed shorter response latencies for the Incongruent test trial compared to Congruent. Both birds responded slower on YC trials, but there was not much consistency between how the birds responded during the rest of the transfer trials at test.

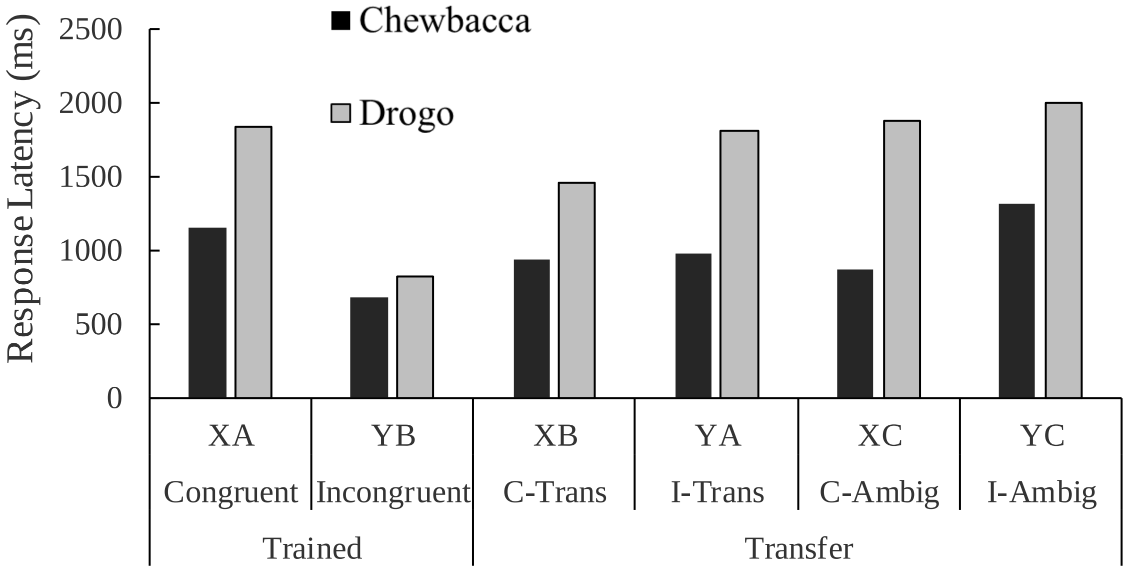


Figure 8. Mean response latency in ms for each of the compatibility types during testing. The figure displays the stimuli as well as the compatibility type during test. The letters "C" and "I" represent the OS from training used in each transfer trial and correspond to the training compatibility type that used that OS (e.g., I corresponds with Incongruent). "Trans" indicates a transfer trial where the OS LM pair utilized the LM from the Incongruent trial and the OS from the Congruent trial, or vice versa. "Ambig" indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training.

Discussion

In Experiment 1a, LM and OS stimuli were designed to be spatially unstable predictors of the location of the hidden goal on their own but were able to reliably predict the location of the goal location during occasion setting trials (e.g., OS + LM). Responses immediately to the left or right of the LM were reinforced depending on the combinations of OS and LM stimuli on each trial and the relative spatial position of the LM in relation to the OS. The different trial types were designed to have differing levels of compatibility in regards to the automatically generated spatial response codes and the required response for each set of stimuli. These compatibility levels were expected to influence subject performance. During test, OS stimuli and LM stimuli were presented in either the same OS pairing as training or one of two transfer types: direct transfer, where the OS and LM from the two stable compatibility types were switched, or ambiguous transfer where the OS stimuli from Congruent and Incongruent training trials were paired with LM C. It was hypothesized that the level of compatibility would influence the speed at which the occasion setting task was learned during training, subjects' magnitude of responding, the amount of conditional control over responding during transfer trials, and response latencies. Compatibility influenced response accuracy and the latency to respond but did not affect the rate of acquisition for the occasion setting task or the ability of the OSs to display conditional control over responding during testing.

Magnitude of responding was used to calculate DR and evaluate whether subjects learned the occasion setting task. It was hypothesized that the incongruent stimulus-response requirement on Incongruent trials would slow down the speed of acquisition of the occasion setting task. Contrary to the hypothesis, in the current task the differing levels of SRC did not influence the rate at which the discrimination was learned. The combined DR revealed that the discrimination was learned despite procedural differences from typical SRC studies, as well as other spatial occasion setting studies (e.g., Fitts & Seeger, 1953; Simon & Rudell, 1967; Ruprecht et al., 2014; Leising et al., 2015; Cleland et al., 2017). The differing levels of compatibility also had no effect on the DR at the end of training or during testing for either bird. After the modification to the OS/LM overlap was made, the data from training and testing demonstrated that both birds learned the occasion setting task within the first block of training

The DR revealed whether subjects inhibited responding during LM alone trials, whereas the mean magnitude reveals the overall excitatory value of each stimulus combination. Inconsistent with previous occasion setting tasks, subjects demonstrated relatively equal amounts of responding across all of the trial types at test. This is unexpected given that Cleland et al. (2017) found that the training history of stimuli in a similar spatial occasion setting paradigm was an accurate prediction of the level of transfer. Based on previous research, the prediction was made that acquired equivalence between A and B would result in more transfer on XB and YA trials than XC and YC. Some transfer can be expected because each of the LMs used in the current study were part of occasion setting trials during training (XA+, YB+, ZC+), but it is surprising that there was not more responding on the trained trial types compared to the direct transfer and ambiguous transfer trials (Bonardi & Hall, 1994). Inconsistencies between how the birds responded on the test trials suggest caution when interpreting these data, but there were some similarities worth discussing. If responding on XA and YB trials was any indication of the overall excitatory value of X and Y, then it is difficult to make sense of the transfer test trials with those OS stimuli. Both birds responded more on Incongruent (YB) trials than Congruent trials (XA) but responded less on YC transfer trials than XC trials. It is possible that the low level of responding for both birds on XA trials compared to YB trials is indicative of less learning about the XA pair than the YB pair. If this is true, then X may be better able to excite responding when paired with C. It may be that learning about YB was so specific to OS Y and LM B that any change to that stimulus set disrupted performance (e.g., YC or XB). If X is acting as more of an OS, and learning on XA trials is less tied to OS X and LM A, then X is better able to transfer control when paired with C. However, without additional tests of individual stimuli or statistical analysis the interpretation is speculative.

Contrary to the prediction, there was a clear accuracy advantage for Incongruent trials compared to Congruent or Ambiguous trials during training. It took longer for both birds to learn to make accurate responses on Congruent trial types than Incongruent trial types. However, by the middle of training, response accuracy on Congruent and Incongruent trials was above chance and there was no difference between the compatibility types. For the first response accuracy during test, when the effect would be expected to be most pronounced, there was no accuracy advantage for the Incongruent trials over Congruent trials. When focusing on all of the responses the Incongruent trials continued to produce higher response accuracy than Congruent trials for both birds. This is most likely due to the fact that subjects had the ability to correct their response during Experiment 1a while the OS was still present on the screen. Additional responding in the presence of the OS likely increased overall accuracy especially if Incongruent trials were producing better accuracy during training. The original prediction of better performance on congruent trials was because of the compatibility between the automatically generated spatial response code for the location of the LM and the response indicated by the spatial positioning between the OS and LM. Any incompatibility between the spatial code for the location of the LM and the required response should have resulted in a decrease in accuracy, especially on the very first response. There are at least two explanations for why there was not an accuracy advantage for Congruent trials. The first explanation centers around the nature of the stimuli in the occasion setting task.

It was predicted that subjects might treat OS Y as a LM. Each individual stimulus was assigned a predictive weight based on its ability to direct responding to the correct goal location on its own based on its proximity, stability, and reliability with the hidden goal. OS Y was assigned a predictive weight of 1.00 because it was extremely close to the goal, stable, and the only stimulus capable of guiding subjects to the hidden goal location without information from any other stimuli. LMs A and B were each assigned predictive weights of .6 because they were close to the goal location but on their own they were only able to narrow down subject responding to two possible response locations. Subjects needed information from an OS stimulus, to find the hidden goal with absolute certainty. OS X was assigned a predictive weight of .4 because it was far away from the goal location and on its own was only able to narrow down subject responding to two possible response locations. LM C was assigned a predictive weight of .2 because it narrowed down subject responding to two possible response locations but even with the help of an OS subjects could only narrow down their responding to two possible response locations. Predictions were generated by weighting each stimulus based on its proximity, stability, and reliability with regards the hidden goal. Predictions for how much each stimulus would control where subjects responded during the transfer test can be seen in Figure 9.

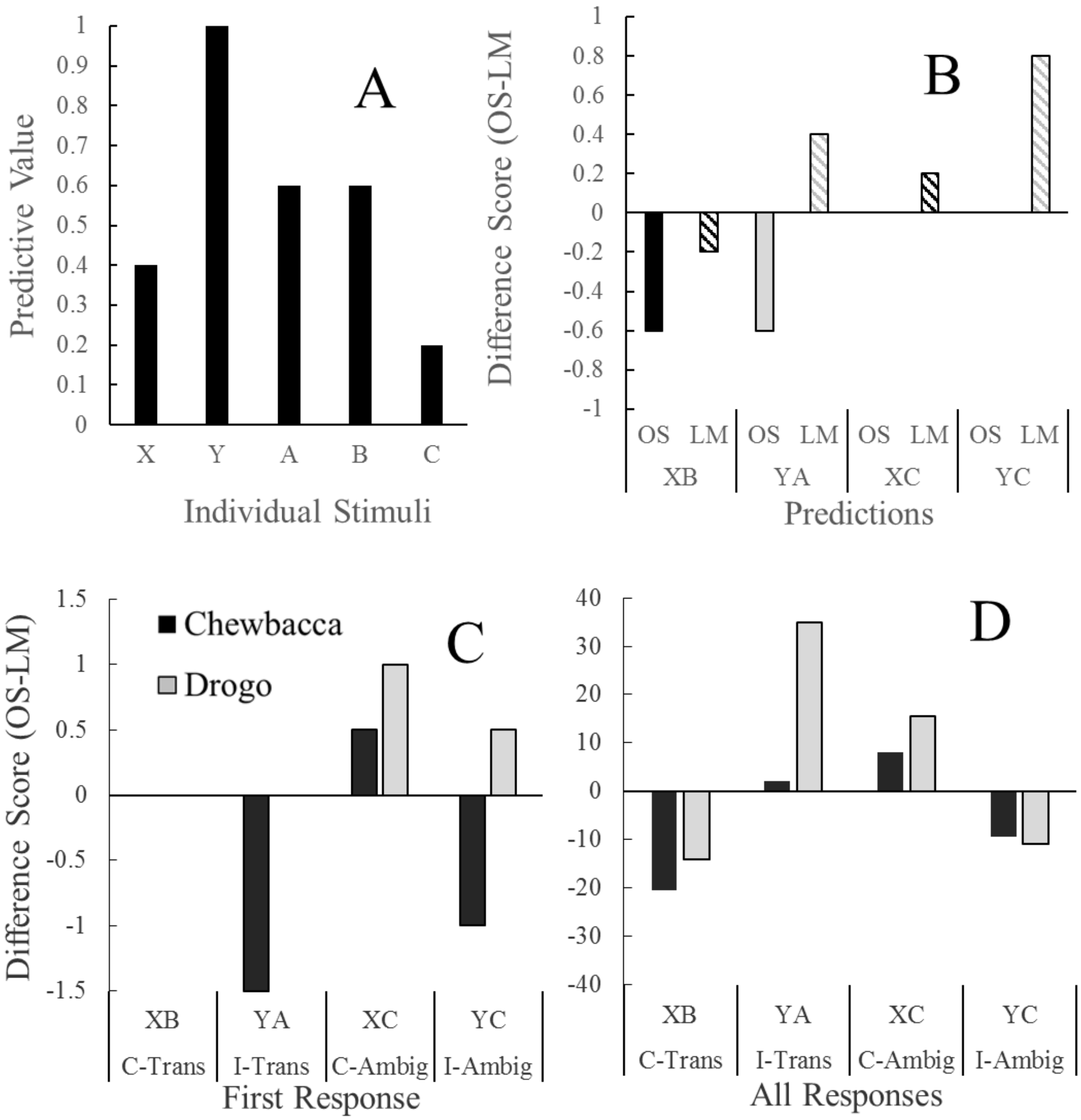


Figure 9. Displays conditional control of spatial responding during the transfer test trials. Panel A displays the predictive value each stimulus was given based on the ability of that stimulus to direct subjects to the correct goal location on its own during training. The prediction panel (B) of the figure was the result of combining the predictive weights of each stimulus and graphing resulting difference scores. Panels C and D display the spatial control data as a difference score based on OS directed responding – Other directed responding for the first response and all responses, respectively, during the transfer tests.

Comparing these predictions to the actual data obtained during testing and focusing on all of the responses (see Figure 9, Panel D) indicates that subjects most likely treated both OS Y and OS X as LMs. If all training stimuli acted as LM stimuli, then Bayes' (1763) theorem can help to explain how two sources of spatial information might be weighted and then combined to guide subject responding. The simplest interpretation and application of the theorem to the current procedure is that a stimulus' weight should be inversely related to that stimuli's variability in predicting the location of the hidden goal (i.e., less variability corresponds with more weighting) (Cheng, Shettleworth, Huttenlocher, & Reiser, 2007). Cheng et al. (2007), in a review of Bayesian spatial integration, also discussed the idea that as uncertainty about the correct response increases for the current stimulus set (e.g. transfer tests) the more previous training is relied on in making a spatial response. In the current experiment all of the transfer trials should have generated uncertainty about the location of the hidden goal because the OS and LM stimuli signaled the goal location at different positions within the response array. This means that all of the stimuli from training (including the OS stimuli acting as LMs) should have displayed conditional spatial control over where responses occurred based on how predictive they were during training. The weights assigned to the stimuli for the prediction (see Figure 9, Panel A) follow this basic idea and predict the recorded data fairly well. The main discrepancy being that the predictive weight LM A gained during training was underestimated, at least for Chewbacca, and the spatial responding of both birds was in the opposite direction predicted by OS Y on YC trials. It might be that because X was so unreliable during training, the relative predictive value of A was enhanced. As mentioned in the results, the counterbalancing for the test trials dictated that both birds receive only YC, not CY, transfer trials. The training history of LM C should have prevented C from gaining any specific spatial control during YC trials but the results indicate that responding was in the opposite direction of the spatial prediction made by OS Y. Therefore, this result may stem from a SRC effect during transfer testing. This possibility is discussed in subsequent paragraphs. The predictive value of the stimuli may also be explained by the spatial positioning of the stimuli.

The higher predictive value of LM A and other stimuli may have been due to the closer proximity of OS Y, LM A, and LM B to the goal location overshadowing the other stimuli they were paired with during training. Occasion setter Y and LM B should be equally proximal and stable regarding the location of the goal. However, OS Y was more reliable than LM B. Occasion setter Y may have gained more spatial and excitatory value than LM B for that reason. Overshadowing of X may have occurred during XA trials even though X was the more reliable stimulus because of the proximity of A to the goal location. Using the same array as in the current procedure, Leising et al. (2011) found that a closer LM overshadowed a LM that was just one response location further from the goal location.

There were mixed results for the birds during testing but for Chewbacca, neither OS Y or LM A were able to control where subjects responded on YA trials. It seems unlikely that the inability of either stimulus to gain clear spatial control across testing was due a lack of learning during training. A learning versus a performance deficit can be evaluated by comparing magnitude of responding for trained and transfer trials at test. Our results indicate that responding for trained and transfer trials was quite similar at test. YA trials produced the most responses during the transfer test and a learning deficit would likely result in weak responding at test, although this was not very consistent between birds. It seems much more likely that subjects learned about the stimuli and spatial control at test was the result of Y and A signaling the goal at different locations.

OS X was able to gain conditional control over responding when it was paired with the LM that did not provide conflicting spatial information (C). This finding indicates that subjects had learned about X but LM B gained spatial control during XB transfer trials for both birds. This finding is consistent with the statement made by Cheng et al. (2007) regarding reliance on previous learning when faced with uncertainty. Although LM A may have overshadowed OS X, which allowed for LM B to control spatial responding during XB transfer trials, the uncertainty present on XC trials could have allowed for X to control spatial responding when paired with LM C. The training histories would have resulted in a hierarchy of predictive value, such that LM B, a more predictive stimulus, was higher than X, which was higher than C.

Lastly, and most surprisingly, OS Y did not demonstrate clear spatial control during YC trials, other than the first response, indicating that when given the chance to make additional responses Y demonstrated less control than C. These results are consistent with the idea that all the stimuli in Experiment 1a were LMs even if they were intended to be OSs and may have masked the effects of SRC. However, the majority of these conclusions are highly speculative without additional transfer tests, single LM tests, or the ability to run group statistics.

There is at least one additional explanation for why Congruent trials did not provide a response accuracy advantage. It is possible that there was more than one stimulus-response compatibility effect at work during each of the occasion setting trials. The task was designed under the assumption that the appearance of the LM to the right or left of the OS would generate an automatic spatial response code in the direction of the appearance of the LM (e.g., Umilta & Nicoletti, 1985; Umilta & Liotti, 1987) even if that response code was not in the same direction as the required response for the stimulus set. When the spatial response code is different than the required response the incompatibility can cause errors, influencing accuracy. It is also possible that during each trial another compatibility effect was working against the automatically generated spatial response code. Early accounts of SRC and Simon effects demonstrated that there is a strong underlying tendency for subjects to respond to or in the direction of the source of stimulation such as a tone or a light (e.g, Fitts & Seeger, 1953; Fitts & Deininger, 1954; Simon & Rudell, 1967). In many ways, a stimulus in a SRC task that appears at the same location the response is required serves the role of a beacon (a LM stimulus close enough to the goal that moving toward it helps subjects find the goal) (e.g., OS Y on YB trials) (Waller, Lippa, 2007). It may be the case that requiring a response to the right of LM A on an XA+ trial was incompatible with the natural tendency to respond to the source of stimulation because the required response was in the direction away from two salient stimuli, or a response beacon, even though a right spatial response code should have formed due to the positioning of the stimuli. On Incongruent trials the required response was always between the OS and LM and was potentially a much more congruent response despite the fact the LM did appear to the right of the OS and may have also generated a right spatial response code that should have been incompatible with the required response. However, this is only speculation as it is impossible to separate compatibility from the OS potentially acting as a LM during Incongruent trials during Experiment 1a.

The Incongruent compatibility type advantage for accuracy was also present for response latency. During training and testing, both subjects responded faster on Incongruent trials than on Congruent or Ambiguous trials. This result is in the opposite direction of what was originally predicted and is still surprising even when considering the accuracy differences from training and testing. Even if subjects were able to overcome the incompatibility effects that were present on Incongruent trials and respond accurately, the conflict created by the direction of stimulation not matching the direction of the required response should have led to slower reaction times (Simon & Rudell, 1967). There are at least three possible explanations for why Incongruent trials produced faster response latencies than Congruent trials.

The simplest of the explanations is based on differences in the physical distance between the OSs and the predicted hidden goal location on Congruent and Incongruent trials. Subjects were required to respond directly to the OS stimulus to advance the occasion setting trial and then make a goal location search response. On Incongruent trials, the OS stimulus was directly beneath the goal location and required a shorter head movement from the OS to the goal location to make a correct response than on Congruent trials. The goal on Congruent trials was always two locations away from OS X and this additional distance seems like a plausible explanation for the response latency advantage that was observed. Second, the hidden goal location on Incongruent trials was always directly above OS Y and could be found without waiting for the LM to appear. Pigeons may have learned to respond before the LM appeared on Incongruent trials before there was even a chance for incompatibility to play a role in influencing the response. However, if the pigeons were responding without being influenced by the spatial position of the LM then response latencies during the transfer test should have been consistently faster for any of the transfer test trials using OS Y. However, this was not observed during the transfer test trials. Lastly, this result is consistent with the above notion that there may be multiple stimulus-response compatibility effects at work during each trial. As explained earlier, requiring a response to the right of LM A on an XA trial may actually be less compatible than the required response on an Incongruent trial because the required response is away from two salient stimuli. Responding to the left of LM B on YB trials may be more congruent and overpower the possible compatibility effect that was expected when requiring a response in the opposite direction of the appearance of the LM.

In conclusion, Experiment 1a demonstrated that pigeons were able to learn an occasion setting task when the correct location was dependent on the spatial position of the OS and LM stimuli. The designed levels of compatibility, congruent and incongruent, did not affect the speed of acquisition of the occasion setting task or DR at the end of training or during testing. Inconsistent with most previous occasion setting literature (e.g., Bonardi & Hall, 1994; Ruprecht et al., 2014; Leising et al., 2015) pigeons produced a similar number of responses on all of the trials at test. Compatibility did not appear to influence the magnitude of responding during testing. Compatibility level produced differences in accuracy as pigeons were more accurate on Incongruent trials during training and during test for all responses. However, there was no difference for the first response data which is the only response that could have shown evidence of a compatibility effect. Lack of consistency between the pigeons on transfer test trials made obtaining a clear picture of which stimuli controlled responding difficult. However, during the transfer test LM B displayed spatial control over responding during XB trials and OS X displayed control during XC, whereas LM A and OS Y displayed less evidence of any clear control over spatial responding. This is especially interesting because both birds were more accurate on YB trials during training and testing than XA. Both pigeons responded with much shorter latencies during training and during testing for the Incongruent trials than the Congruent trials, but neither of the OS stimuli provided any response latency advantage during the transfer tests. These results indicate that the pigeons were more accurate and responded faster on Incongruent trials, but that this advantage on trained trial types did not necessarily translate to any advantage when OS Y was paired with other LM stimuli during the transfer tests.

Thus far the results have been interpreted in terms of an elemental approach, which assumes that each stimulus gains some predictive value based on its own reliability, stability, and proximity to the hidden goal. However, the OS and LM remained on the screen for most of the duration of a trial and were both present when reinforcement was earned. Consequently, an alternative is that the task was learned configurally where the birds treated the individual OS and LM stimuli on each trial as one distinct stimulus that informed whether or not, and where a response should occur to obtain reinforcement. However, learning was approached as elemental for three reasons. The first is that previous research (e.g., Ruprecht et al., 2014; Leising et al., 2015; Cleland et al., 2017) suggests that stimuli on occasion setting trials in this paradigm are learned about independently of one another. The second is that the design of the current experiment specifically discouraged configural learning by spatiotemporally separating the OS and LM for at least part of the occasion setting trial, and using a discrete OS that moves around the display from trial to trial. The third reason is that even if pigeons learned about the OS and LM stimuli as a configuration and not exclusively individual elements, which Schmajuk, Lamoureux, and Holland (1998) indicate may happen during any task (even those designed to discourage configural learning), the overall performance predictions in this task aren't different from those derived from learning about each element alone.

There are no additional pigeon results to discuss but the findings from additional human experiments further support the idea of an elemental approach to learning and the overall conclusion that SRC effects influence occasion setting performance but only on measures associated with a typical SRC task (i.e., accuracy, response latency) and not those typically associated with an occasion setting task (DR, acquisition of the discrimination, or transfer of conditional control of responding).

Experiment 1b: Long Duration Proximal Occasion Setting Stimulus - Humans

Method

Participants

Forty-five undergraduate psychology students from Texas Christian University (TCU) (*n* = 25) and Arcadia University (AU) (*n* = 20) participated in Experiment 1b as partial fulfillment of psychology course requirements. None of the participants had any previous experience with the experimental design and all participants remained uninformed of the true nature of the study until being debriefed following completion of the study. The entire experiment, including all instructions, training, testing, and debriefing lasted less than 40 minutes. All experiments were conducted in a human cognition lab located at TCU, or in one of the five identical human participant research rooms at AU. All research was conducted according to TCU's Human Participant Ethics Committee as well as an approved IRB protocol from both universities. All experimenters completed training in the ethical treatment of human participants through an online course, "Protecting Human Research Participants".

Apparatus

All training and testing of human participants was conducted using a Hewlett Packard Touchsmart computer (9300 Elite AiO) or a Dell laptop (Latitude E5470). The touchscreen and laptop displayed the stimuli and were capable of recognizing touches and mouse clicks, respectively, as responses.

Touchscreen stimuli

As in Experiment 1a, the visual stimuli used in Experiment 1b fell into one of three stimulus categories: response location, occasion setter, or landmark. The colors, positioning, and counterbalancing of the stimuli were identical to Experiment 1a. The response locations were a set of eight squares that measured 2 cm^2 and were equally spaced 2.2 cm apart (center to center). The row of response locations was presented 16 cm from the bottom of the screen. An image of a treasure chest that measured 2.25 cm x 3 cm served as the reinforcer for correct responses and appeared at the bottom of the screen, centered between the two middle response locations (4 & 5).

Procedure

Positioning of participant.

Participants were seated in a chair located .6 meters from the computer screen after filling out an informed consent document. To the knowledge of the experimenter this position was maintained by the participant throughout the experiment.

Pretraining 1.

Prior to Pretraining 1, the participants were read the following script by a trained experimenter:

> *"Behind one of these boxes is a hidden treasure and your task is to find the box which reveals it. Sometimes the treasure will be revealed after a single click to the correct box, but on other trials you may have to click the same box several times. Take this opportunity to find the treasure 3 or 4 times.*

Participants were allowed to explore the screen and make responses to each of the eight response locations until they found the box that revealed the hidden treasure. After the participant successfully located two more hidden treasures (for a total of three successful searches) they were advanced to Pretraining 2.

Pretraining 2.

Prior to Pretraining 2, the participants were read the following script by a trained experimenter:

"Hopefully you noticed that the box hiding the treasure was not always the same during the practice. During the actual experiment you will be given a little more information about which of the 8 gray boxes is hiding the treasure. During the experiment there will be some scenarios when a colored box will appear directly below one of the gray response boxes. You must respond directly to the colored box to advance the scenario. Take this opportunity to click the colored box and respond to different locations to find the hidden treasure"

Participants were allowed to respond to the colored boxes that appeared on the screen and make responses to each of the eight response locations until they found the box that revealed the hidden treasure. After the participant successfully located two more hidden treasures (for a total of three successful searches) they were advanced to occasion setting training.

Occasion setting training.

Prior to occasion setting training participants were read the following script by a trained experimenter:

"During the practice session the colors and patterns in the boxes had no relationship but during the actual experiment please pay close attention to the colored boxes and the colored patterns that appear. They will help you find the box that is hiding the treasure. On each scenario there will only be one box hiding the treasure. If you have found the treasure keep responding to the same box to get as much treasure as possible. Is this clear?"

"This is very important. During the experiment the will be some scenarios where finding treasure is not possible. This means that no matter where you respond or how many times you click a gray box you will not find treasure. If you believe that you have figured out a scenario where there is no treasure present it is in your best interest to stop responding and wait for a new scenario to begin. You will know a new scenario has begun when the gray boxes go black for a few seconds and then refill with gray. This is a learning task so early on during the experiment you will want to explore all of the gray boxes to determine which one is hiding the treasure. On trial when there is a treasure present you should be able to find the treasure without making any mistakes. Do you have any questions?"

"Again, it is your task to find as much treasure as possible. Remember that there is only one box hiding the treasure during a given scenario but once you find the treasure you can respond multiple times to continue receiving treasure. You will only have a limited amount of

time to search for treasure on each scenario so try to respond as quickly and accurately as possible and please do not click at random. If you find the treasure it will appear in the bottom of the screen just like during the practice sessions."

"Learning to distinguish the different scenarios, that is, figuring out how to respond to reveal the treasure will reflect your performance and determine the duration of the experiment. The better you do the faster you will finish. Remember you must click the colored boxes that appear beneath the gray boxes for the trial to progress."

"At some point a box will appear in the center of the screen that says 'Stop! Do not touch! Please get the experimenter' When this happens, come get the me in the hallway and I will read you a final set of instructions."

All details of occasion setting training for Experiment 1b were the same as Experiment 1a, including the same nine distinct trial types from Experiment 1a (see Table 2). Informed by the results of Experiment 1a, Experiment 1b presented the occasion setting stimuli for the full duration of the occasion setting trials instead of limiting the overlap between the OS and LM to 1 s as in the first 63 sessions of Experiment 1a with the pigeons. Responses made to the hidden goal location were rewarded, until stimulus offset (i.e., it is possible that participants received multiple reinforcements per trial), with a 2-s access to the image of an opened treasure chest followed by a 2-s inter-trial interval (ITI) prior to the start of the next trial.

Criterion to advance to test.

All human participants were advanced to testing regardless of their performance during occasion setting training after 72 trials. As participants moved through the blocks of trials the response requirement increased from a continuous reinforcement schedule (CRF) during the first block where each correct response to the hidden goal was rewarded with a treasure presentation, to a RR-4 schedule of reinforcement where each response to the hidden goal had a 25% chance of treasure presentation. After completing the occasion setting training, the participants received a message on the monitor that informed them to find the experimenter for further instruction before testing.

Test.

Prior to testing participants were read the following script by a trained experimenter:

> *"On scenarios after this signal, you should still do your best to find the location that previously hid the treasure, but no treasure will be shown. However, we are still keeping track. We want to know where you think the treasure is located. Please click where you believe the treasure would be. Many responses to a box is an indication a high level of confidence as to where the treasure would be, and fewer responses indicate less confidence. At the end of the session you will see a big white box appear on the screen along with some words and numbers. When this appears the experiment is over. Please do not touch anything on the screen and come and get the experimenter."*

Following the reading of the script participants received two shuffled blocks of 13 non-reinforced test trials: Previously Trained: AX, XA, BY, YB, A, B, and C and Novel Combo: BX, XB, AY, YA, and XC, YC or CX, CY (see Table 2). The order of trial presentation was counterbalanced across participants and the duration of the ITIs, OS stimuli, and LM stimuli as well as the onset of the stimuli were the same as training.

Debriefing.

After the testing phase of the experiment was completed the experimenter debriefed each participant and asked a series of questions to help gauge the level of the participant's understanding as well as to reveal the true nature of the experiment (see Appendix A).

Results

Participants with a combined spatial accuracy for the first response on trained trial types at test (XA, YB) that was not significantly above chance (.5) were removed from the analysis. This resulted in the data from 15 of the 45 participants being removed. The data from the remaining 30 participants were included in the analysis.

Behavioral Measures and Description of Data Analysis

Prior to running any analyses on the data, a two-way ANOVA was conducted to examine the effects of location (AU vs. TCU) and compatibility level (Congruent, Incongruent, &

Ambiguous) on performance for each dependent variable in the experiment. Across all dependent variables there were no statistically significant interactions between location and compatibility level. All additional data analyses were conducted on the combined participant data (AU & TCU) for each of the dependent variables.

All other recorded behavioral measures and data analysis for Experiment 1b were identical to those in Experiment 1a.

Occasion Setting

Training.

Discrimination ratios for each compatibility type (Ambiguous, Congruent, & Incongruent) were compared to chance, .5, to determine at what point during training responding was above chance. Compatibility level did not affect when DRs were above chance. The DRs for Ambiguous, (*M* = .78, *SD* = .31), Congruent (*M* = .70, *SD* = .30), and Incongruent (*M* = .76 *SD* = .30) trials were significantly greater than chance for the first time during third block of training, *ps* < .01. Figure 10 displays combined occasion setting DR across the eight blocks of training. Occasion setting DR steadily increased across the eight blocks of training (see Figure 10). A one-way repeated measures ANOVA conducted to compare the effect of compatibility (Ambiguous, Congruent, & Incongruent) type on mean DR during the last two blocks of training revealed no effect of compatibility type, *F*(2.00, 56) = .18, *p* > .05. A single-sample *t*-test was conducted on the DR for the combined compatibility types to determine if their mean DR was significantly different than .50, chance responding on occasion setting trials, during the last two blocks of training. The combined mean DR (*M* = .83, *SD* = .20), was significantly above chance, *t*(29) = 9.30, *p* < .001.

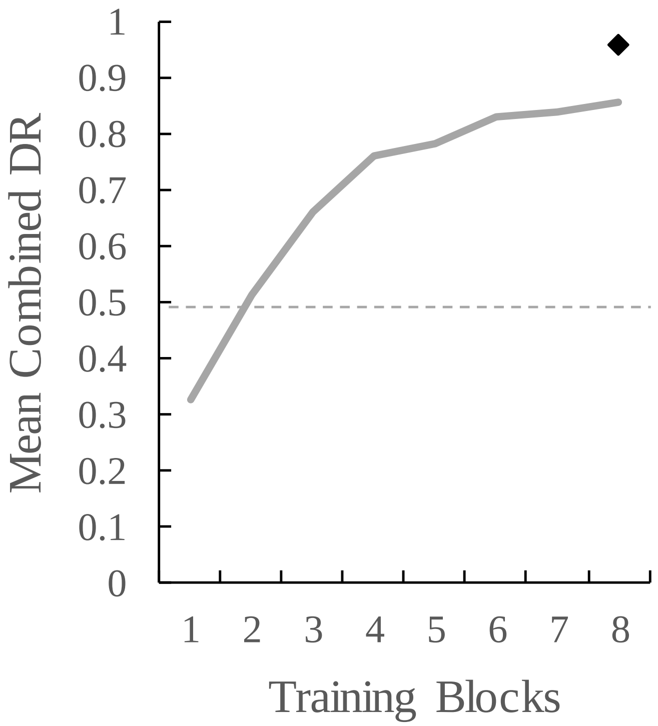


Figure 10. Mean combined discrimination ratio (Ambiguous, Congruent, & Incongruent) across training blocks (9 trials per block) (gray line) and the mean combined discrimination ratio at test (black diamond). The dotted gray line represents chance level of responding.

Testing.

The DR for Congruent and Incongruent trials were compared to one another with a paired-samples *t*-test to determine if there was an effect of compatibility type. The DR for Congruent trials (*M* = .97, *SD* = .08) and Incongruent trials (*M* = .97, *SD* = .08) were not significantly different, *t*(29) = .17, *p* > .05. A single-sample *t*-test was conducted on the mean DR for the combined Congruent and Incongruent compatibility types to determine if their mean DR was significantly different than .50 during testing. The combined mean DR (*M* = .97, *SD* = .07) was significantly above chance, *t*(29) = 34.40, *p* < .001. Figure 10 displays the combined mean DR in relation to the blocks of training.

Magnitude of Responding.

Testing.

A one-way ANOVA with a Greenhouse-Geisser correction was conducted to determine whether responding differed for any of the LM alone (A, B, C) trial types during test. The analysis did not reveal a significant effect of trial type $F(1.17, 33.93) = 1.76$, $p > .05$, so responding on LM trials was collapsed for analysis. A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of stimulus set type (LM, Ambiguous, Congruent, Incongruent, C-Trans, I-Trans, C-Ambig, I-Ambig) on the magnitude of responding revealed a significant effect of compatibility type, $F(2.30, 66.63) = 27.92$, $p < .001$. Planned comparisons revealed that there was significantly less responding during LM ($M = .51$, $SD = 1.31$) trials during test compared to all other stimulus sets, $p < .001$. However, none of the other expected differences were significant (e.g., Congruent vs. Incongruent; C-Trans vs. I-Trans). Magnitude was collapsed across test stimulus sets (trained, direct transfer, and ambiguous transfer) and a one-way repeated measures ANOVA with a Greenhouse-Geisser correction revealed a significant effect, $F(1.53, 44.37) = 26.30$, $p < .001$. Planned comparisons revealed that participants responded most on trained stimulus sets ($M = 94.65$, $SD = 74.21$), followed by direct transfer stimulus sets ($M = 64.93$, $SD = 56.58$), $p < .01$ and responded the least on ambiguous transfer stimulus sets ($M = 28.73$, $SD = 29.63$), $p < .01$. Magnitude was also collapsed for compatible OSs (i.e., XA, XB, & XC) and incompatible OSs (i.e., YB YA, & YC) at test. A paired-samples *t*-test revealed that participants responded similarly during incompatible ($M = 66.63$, $SD = 55.23$) and compatible ($M = 58.91$, $SD = 44.92$) trials during test, $t\ (29) = -1.62$, $p > .05$. Figure 11 displays the mean magnitude of responding for each stimulus type during testing.

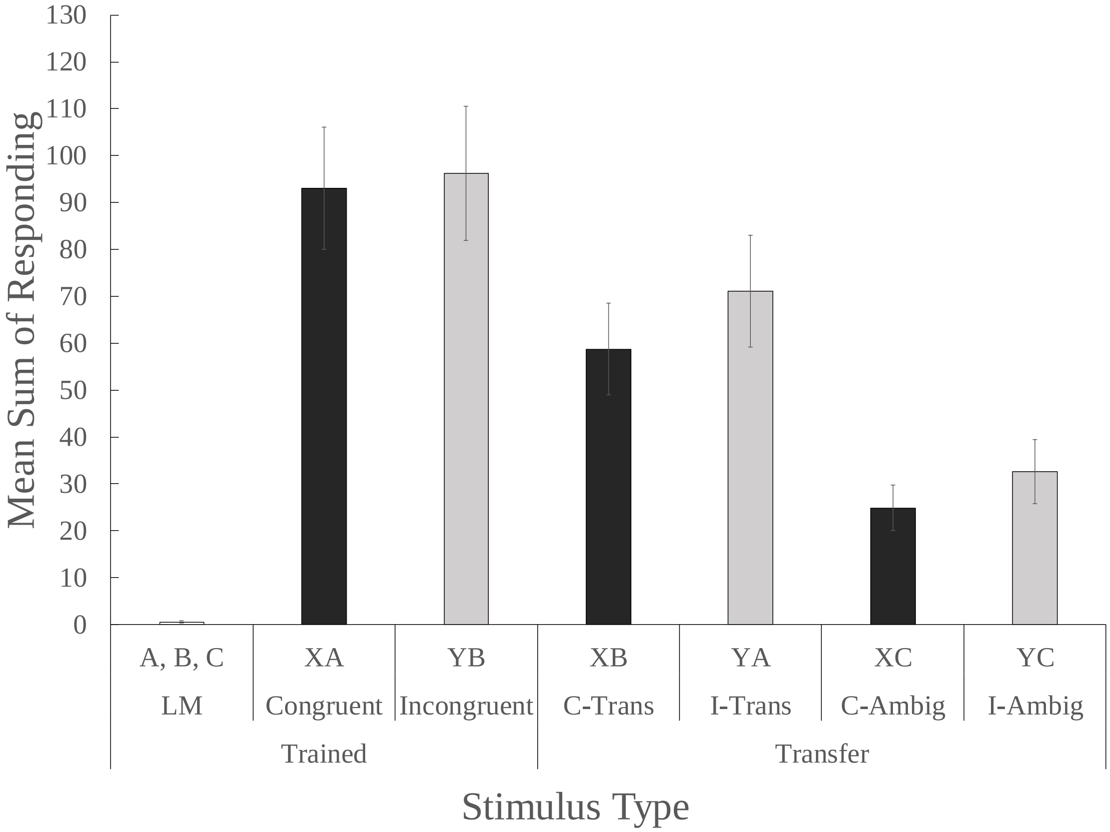


Figure 11. Magnitude of responding during test. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled "Trained". Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled "Transfer". The letters "C" and "I" represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., "I" corresponds with Incongruent). "Trans" indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. "Ambig" indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. Responding on LM alone trials was collapsed across trial types (A-, B-, C-). Error bars represent standard errors of the means**.**

Accuracy and Difference Score

Training.

A one-way repeated measures ANOVA was conducted to compare the effect of compatibility type (Ambiguous, Congruent, Incongruent) on response accuracy for the first response to one of the eight response locations after the OS had been touched during the last two blocks of training. The results demonstrated a significant effect of compatibility type, $F(2,58) = 25.00$, $p < .001$. Planned comparisons demonstrated that participants were significantly more accurate on Incongruent trials ($M = .89$, $SD = .23$) than on Congruent ($M = .62$, $SD = .35$), $p < .001$ or Ambiguous ($M = .50$, $SD = .25$) trials, $p < .001$. There was no difference in accuracy between Congruent ($M = .62$, $SD = .35$), and Ambiguous ($M = .50$, $SD = .25$) trials, $p > .05$. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Incongruent trials, $t(29) = 9.24$, $p < .05$, but not for Congruent or Ambiguous trials, $ts(29) < 1.94$, $ps > .05$. Figure 12 displays the mean response accuracies for each compatibility type during the last two block of training.

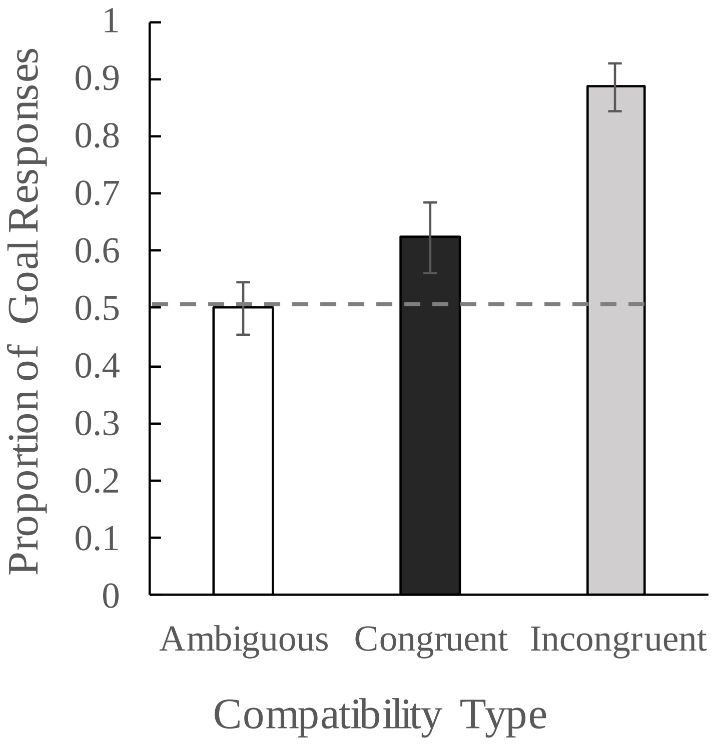


Figure 12. Mean proportion of responses occurring at the correct goal location for each compatibility type during the last two blocks of training for the first response only. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means**.**

Testing.

First response.

A paired-samples *t*-test conducted on the mean of the first response to one of the eight response locations after the OS had been touched to determine if participants responded more accurately during one of the training compatibility types (i.e., Congruent & Incongruent) than the other at test revealed no significant difference in accuracy for Incongruent (M = .90, SD = .18) or Congruent (M = .84, SD = .20) trials at test, $t(29) = -1.08$, $p > .05$. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Congruent and Incongruent trials, $ts(29) > 9.10$, $ps < .001$.

As previously stated a difference score was calculated for transfer trials at test to get a measure of spatial control. The difference score for each transfer trial type (XB, YA, XC, YC) was compared to zero with a single-sample *t*-test. Transfer trial XB (*M* = -1.20, *SD* = 2.91) *t*(29) = -2.26, *p* < .05 and YC (*M* = .90, *SD* = 1.40) *t*(29) = 3.53, *p* < .01 were significantly different than zero at test. Figure 13 displays the mean first response accuracies for each compatibility type and the difference score for transfer trials during test.

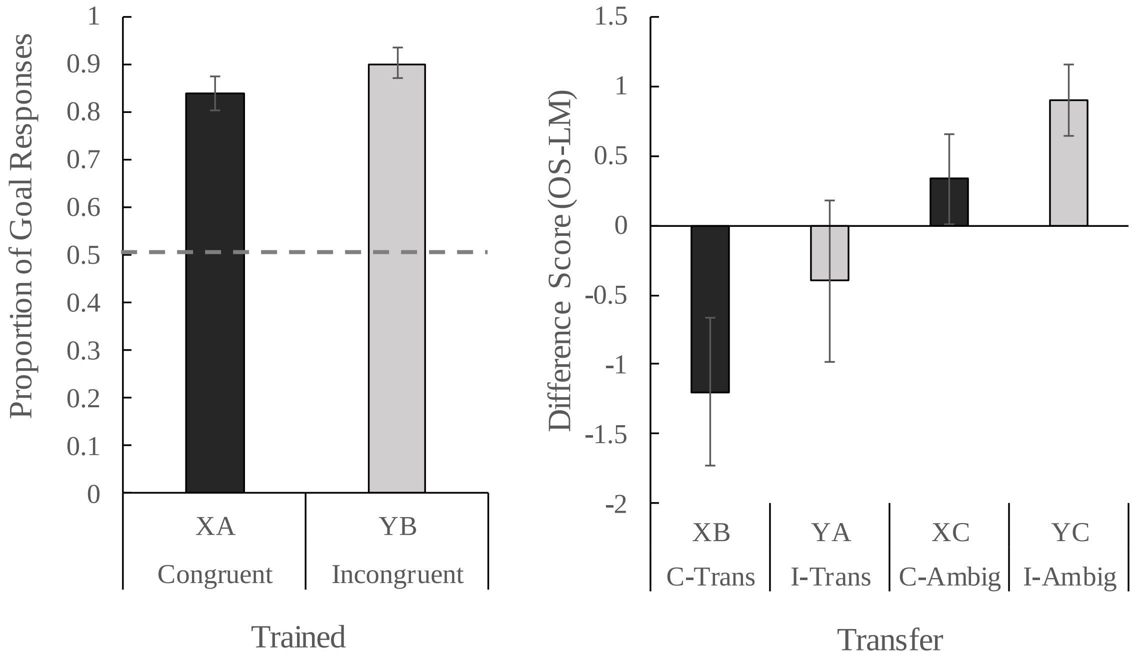


Figure 13. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for first response only. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled “Trained”. Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled “Transfer”. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., “I” corresponds with Incongruent). “Trans” indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS

from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means**.**

All Responses.

A paired-samples *t*-test conducted on the mean of all responses to one of the eight response locations after the OS had been touched to determine if participants responded more accurately during one of the training compatibility types (i.e., Congruent & Incongruent) than the other at test revealed that participants were significantly more accurate on Incongruent trials (*M* = .91, *SD* = .17) than on Congruent (*M* = .85, *SD* = .23) at test, *t*(29) = -2.24, *p* < .05. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Congruent and Incongruent trials, *ts*(29) > 8.25, *ps* < .001.

As previously stated a difference score was calculated for transfer trials at test to get a measure of spatial control. The difference score for each transfer trial type (XB, YA, XC, YC) was compared to zero with a single-sample *t*-test. Transfer trials XC, (*M* = 11.60 *SD* = 29.70), *t*(29) = 2.14, *p* < .05, and YC, (*M* = 17.20, *SD* = 42.34), *t*(29) = 2.23, *p* < .05, were different than zero at test. Figure 14 displays the mean response accuracies for each compatibility type and the difference score for transfer trials for all responses during test.

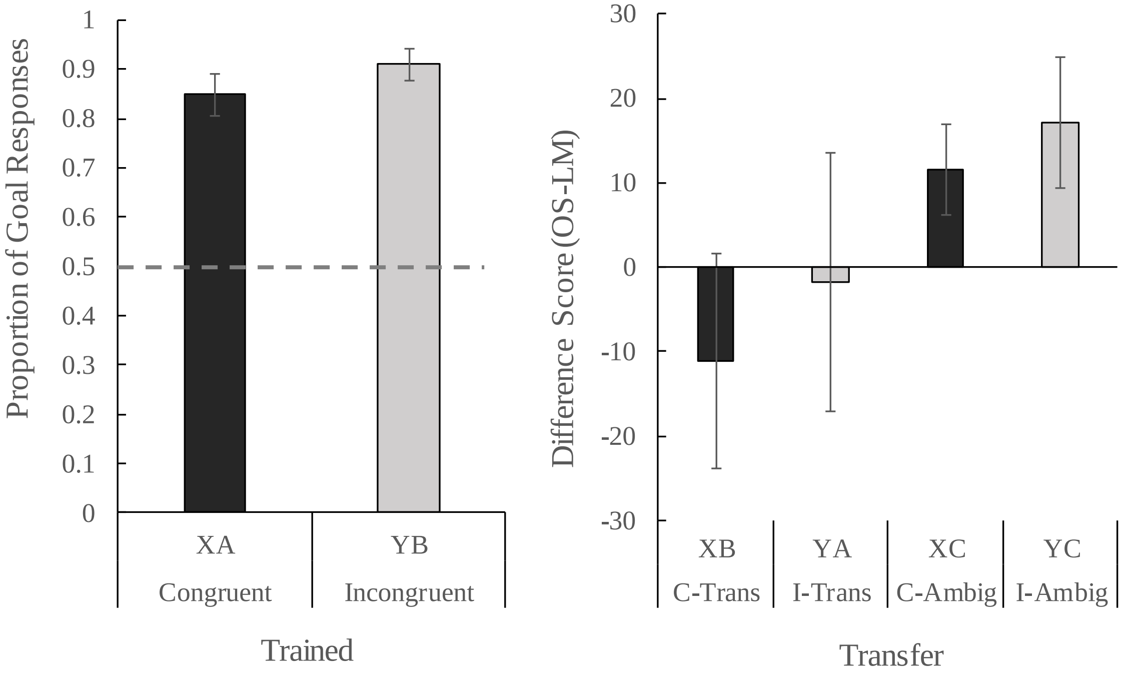


Figure 14. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for all the responses at test. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled “Trained”. Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled “Transfer”. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., “I” corresponds with Incongruent). “Trans” indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means.

Response Latency

All statistical analyses for response latency were conducted on the log transformed data (Lg10) and raw data were used for the figures and descriptive statistics.

Training.

A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of compatibility type (Ambiguous, Congruent, Incongruent) on response latency during the last two blocks of training revealed a significant effect of compatibility type, *F*(1.6, 44.12) = 13.21, *p* < .001. Planned comparisons demonstrated that participants responded significantly faster on Incongruent trials (*M* = 950, *SD* = 55.00) than on Congruent trials (*M* = 1165.77, *SD* = 63.67), *p* < .001 or Ambiguous trials (*M* = 1174, *SD* = 60.08), *p* < .001. There was no difference in response latency between Congruent trials (*M* = 1165.77, *SD* = 63.67) and Ambiguous trials (*M* = 1174, *SD* = 60.08), *p* > .05. Figure 15 displays the raw data mean response latencies for the different compatibility types during training.

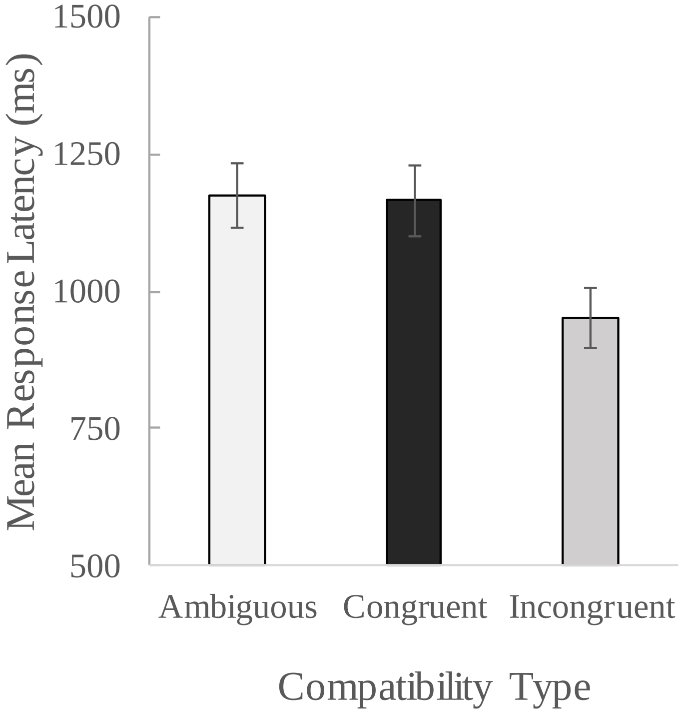


Figure 15. Response latency in ms for each of the compatibility types during the last two blocks of training. Error bars represent standard errors of the means**.**

Testing.

A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of stimulus set type (Congruent, Incongruent, C-Trans, I-Trans, C-Ambig, I-Ambig) on response latency revealed a significant effect of compatibility type at test, *F*(3.62, 83.34) = 5.00, *p* < .01. Planned comparisons revealed the participants had a faster mean response latency for I-Ambiguous (*M* = 1262.69, *SD* = 92.22) than C-Ambiguous (*M* = 1561.13, *SD* = 93.21) during test, p < .01. Figure 16 displays the raw data mean response latencies for the different stimulus set types at test. Differences in response latencies were expected at test, especially for the originally trained trial types (i.e., Congruent & Incongruent). A paired-samples *t*-test was conducted on the mean response latencies for Congruent and Incongruent trials at test revealed no significant difference in response latency for Congruent trials (*M* = 1278.81, *SD* = 54.80) and Incongruent (*M* = 1198.56, *SD* = 54.64) at test *t*(29) = 1.46, *p* > .05. Response data were collapsed for compatible OSs (i.e., XA, XB, & XC) and incompatible OSs (i.e., YB YA, & YC) at test. A paired-samples *t*-test revealed that participants responded significantly slower on compatible (*M* = 1407.47 *SD* = 292.91) than incompatible (*M* = 1270.96, *SD* = 301.45) trials during test, *t*(29) = 2.77, *p < .05.*

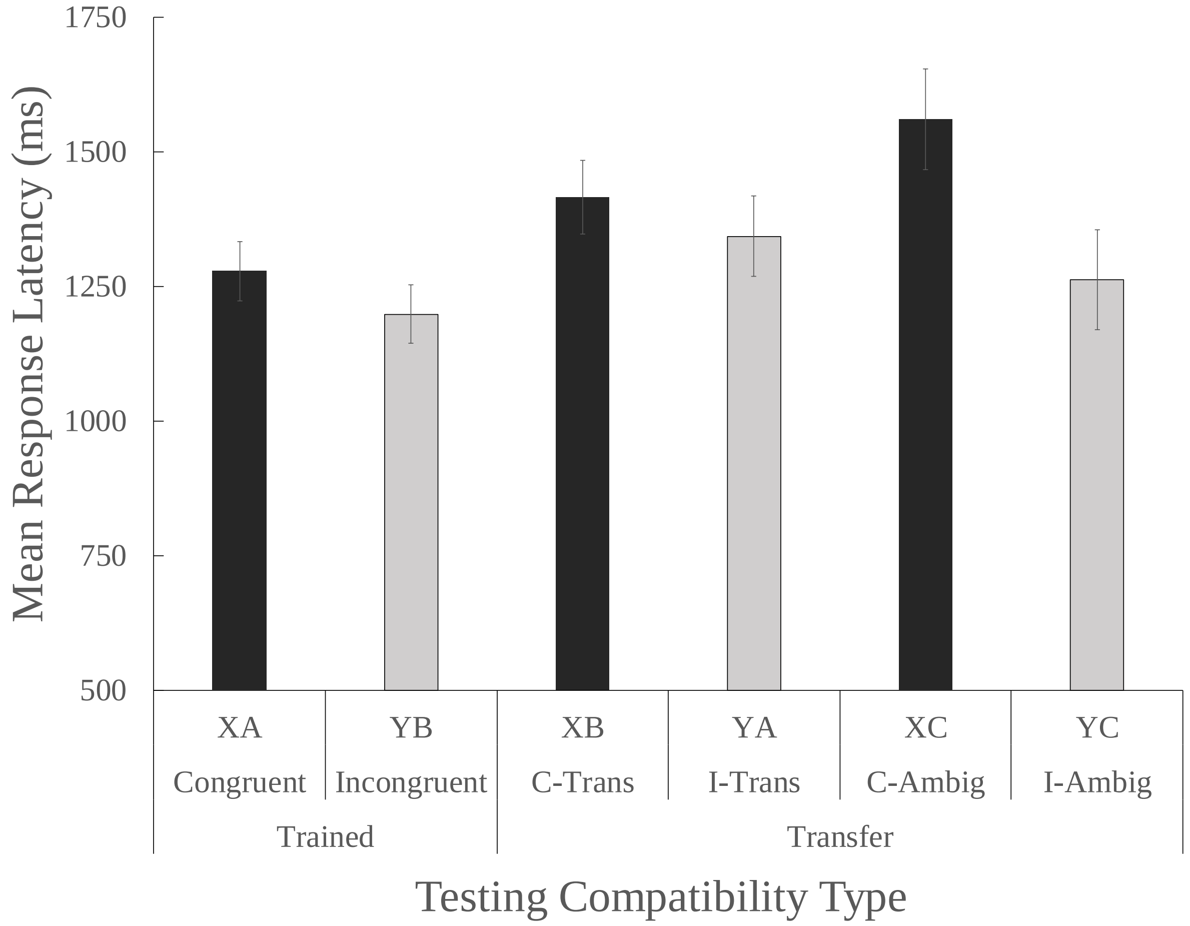


Figure 16. Mean response latency in ms for each of the compatibility types during testing. The figure displays the stimuli as well as the compatibility type during test. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type that used that OS (e.g., I corresponds with Incongruent). “Trans” indicates a transfer trial where the OS LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. Error bars represent standard errors of the means**.**

Discussion

In Experiment 1b, LM and OS stimuli were by themselves spatially unstable predictors of the location of the hidden goal but on occasion setting trials (e.g., OS + LM) were together able to reliably predict the goal location. Responses immediately to the left or right of the LM were reinforced depending on the combinations of OS and LM stimuli on each trial and the relative spatial position of the LM in relation to the OS. As in Experiment 1a, trial types were designed to produced SRC effects that could be compared to one another at test to illustrate how compatibility influences what participants learned about the stimuli and how that learning influenced performance. It was hypothesized that the level of compatibility would influence the speed at which the occasion setting task was learned during training, participants' magnitude of responding, the amount of conditional control over responding during transfer trials, and response latencies. Compatibility produced accuracy and response latency differences between Congruent and Incongruent trials but did not influence the acquisition rate of the occasion setting discrimination or whether the OSs displayed conditional control over responding during transfer tests.

The acquisition rate of the occasion setting discrimination was not affected by compatibility type, as in Experiment 1a. While no differences in the DRs were expected for the different compatibility types by the end of the training session, it was hypothesized that the incongruent stimulus-response requirement on Incongruent trials would slow down the speed of acquisition of the occasion setting discrimination. Contrary to the hypothesis, in the current task differing SRC levels did not influence the rate at which the discrimination was learned. There were also no differences in the discrimination ratios at the end of training for any of the compatibility types (Congruent, Incongruent, or Ambiguous) or at test for the Congruent and

Incongruent compatibility types. At the end of training and during the non-reinforced test trials the combined DR was above chance levels of responding, which indicates the participants learned the basic occasion setting task (respond during OS-LM trials but not on LM alone trials). The combined DR revealed that the discrimination was learned despite procedural differences from typical SRC studies, as well as other spatial occasion setting studies (e.g., Ruprecht et al., 2014; Leising et al., 2015; Cleland et al., 2017).

The DR reveals whether participants inhibited responding during LM alone trials, whereas the mean magnitude reveals the overall excitatory value of each stimulus combination. Magnitude data were only analyzed for testing trial types because participants were receiving reinforcement on some trials but not others during training, which may result in more responding on trials when they were less accurate and less responding on trials in which they were more accurate and consuming the reinforcer.

Consistent with previous occasion setting tasks, participants demonstrated more responding on trained occasion setting trial types (XA, YB) at test than during the direct transfer trials (XB, YA). Cleland et al. (2017) also found that the training history of stimuli in a similar spatial occasion setting paradigm was an accurate predictor of the level of transfer observed when OSs from training were paired with LMs whose training history differed. With this literature in mind, it was predicted that acquired equivalence between A and B should also have resulted in more transfer on XB and YA trials than XC and YC. Indeed, this is exactly what was observed at test. Each of the LMs used in the current study were part of occasion setting trials during training (XA+, YB+, ZC+) so there should have been some degree of transfer due to generalization between the stimuli (Bonardi & Hall, 1994). Participants responded more on the originally trained trial types (XA, YB) than when the spatial information conflicted during transfer trials (e.g., XB, YA), and responded the least when OS X or Y from training was placed in a novel pairing with LM C (the least stable LM from training). However, the level of compatibility (congruent, incongruent) did not appear to affect the ability of the OS to control how much participants responded during novel transfer tests. Compatibility level did not affect the participant's ability to learn the occasion setting task or the excitatory value of each stimulus. The measures discussed thus far indicate how much responding occurred during each trial, where accuracy indicates where participants responded. Responding primarily at the goal, or high accuracy, was expected on Congruent trials compared to Incongruent or Ambiguous trials.

Contrary to predictions, there was a clear accuracy advantage for Incongruent trials compared to Congruent trials during training and testing but only when all responses were included in the analysis of the test. For the first response accuracy, when the effects of SRC would be expected to be most pronounced, there was no accuracy advantage for the Incongruent trials over Congruent trials at test. A difference on all responses and not the first response only is most likely due to the fact that participants had the ability to correct their response during Experiment 1b while the OS was still present on the screen. It was predicted that Congruent trial types would result in higher response accuracy than Incongruent or Ambiguous trial types because of the compatibility between the automatically generated spatial response code for the location of the LM and the response indicated by the spatial positioning between the OS and LM.

Incompatibility between the automatically generated response code for the spatial location of the LM and the required response for the relationship between the OS and LM should have resulted in decreased accuracy, especially on the first response. There are at least two explanations for why Congruent trials did not provide an advantage. As in Experiment 1a, the first explanation centers around the nature of the stimuli in the occasion setting discrimination.

It was predicted that participants might treat OS Y as a LM. Each individual stimulus was assigned a predictive weight based on its ability to direct responding to the correct goal location on its own based on its proximity, stability, and reliability with the hidden goal. OS Y was assigned a predictive weight of 1.00 because it was extremely close to the goal, stable, and the only stimulus capable of guiding participants to the hidden goal location without information from any other stimuli. LMs A and B were each assigned predictive weights of .6 because they were close to the goal location but on their own they were only able to narrow down participants responding to two possible response locations. Participants needed information from an OS stimulus, to find the hidden goal with absolute certainty. Occasion setter X was assigned a predictive weight of .4 because it was far away from the goal location and on its own was only able to narrow down participant responding to two possible response locations. LM C was assigned a predictive weight of .2 because it narrowed down participant responding to two possible response locations but even with the help of an OS participants could only narrow down their responding to two possible response locations. Predictions on the ability of each stimulus to gain conditional control over where participants would respond during the transfer test can be seen in Figure 17.

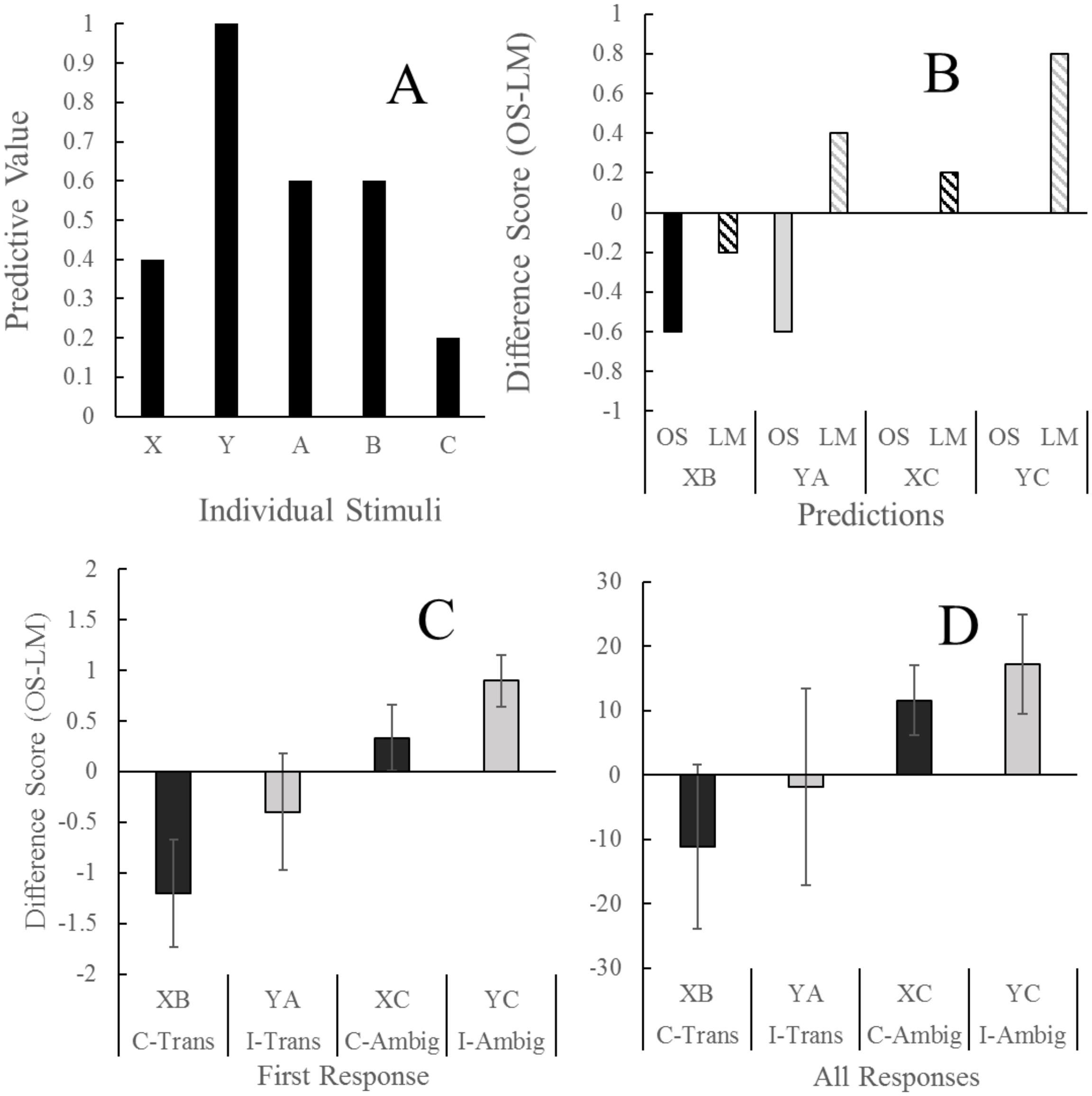


Figure 17. Displays conditional control of spatial responding during the transfer test trials. Panel A displays the predictive value each stimulus was given based on the ability of that stimulus to direct participants to the correct goal location on its own during training. Panel B displays the predictions made for transfer of conditional control assuming the OSs during training were treated as OSs (OS) and assuming the OSs, were acting as LM stimuli. The prediction panel (B) of the figure was the result of combining the predictive weights of each stimulus and graphing resulting difference scores. Panels C and D display the spatial control

data as a difference score based on OS directed responding – Other directed responding for the first response and all responses, respectively, during the transfer tests.

Comparing these predictions to the actual data obtained during testing (see Figure 17) indicates that participants treated both OS Y and OS X as LMs. If all training stimuli acted as LM stimuli, then Bayes' (1763) theorem is helpful in understanding how two sources of spatial information might be weighted and then combined to guide participant responding. As previously discussed, as uncertainty about stimulus increases then its weight is reduced, as well as, previous training is relied on in making a spatial response. In the current experiment all of the transfer trials should have generated uncertainty about the location of the hidden goal because the stimuli did not indicate the same spatial information. As in Experiment 1a, the main discrepancy was that the predictive weight LM A gained during training was underestimated. It might be that because X was so unreliable, the relative value of A was enhanced.

As in Experiment 1a, the closer proximity of OS Y, LM A, and LM B to the goal location may have overshadowed the other stimuli they were paired with during training, possibly enhancing the predictive values of some stimuli. It seems unlikely that the inability of either stimulus to gain spatial control was due to a lack of learning during training because YA trials produced the highest number of responses during the transfer test and a learning deficit would likely result in weak responding at test. It seems much more likely that participants learned about both stimuli, but during test Y and A signaling the goal at different locations produced weak spatial control. Occasion setter Y was able to gain conditional control over responding when it was paired with LM C, the only LM that did not provide conflicting information about the location of the hidden goal indicating that participants had learned about Y. This is consistent with Cheng’s (2007) statement regarding the reliance on previous learning in the presence of uncertain stimuli. LM B gained conditional control over where responding occurred during XB transfer trials but only for the first response. If OS X was overshadowed by LM A, because LM A was more proximal to the goal during training, this would allow LM B to control spatial responding during XB transfer trials. However, LM B did not demonstrate control when all responses were analyzed. Lastly, and most surprisingly, OS X was able to demonstrate spatial control during XC trials indicating that when given the chance to make additional responses X demonstrated more control than C. These results are consistent with the idea that all the stimuli in Experiment 1b were LMs even if they were intended to be OSs. However, the majority of these conclusions are unfortunately speculative without additional transfer tests and single LM tests.

A second explanation may be that as in Experiment 1a there was more than one stimulus-response compatibility effect at work during each of the occasion setting trials and that the required responses on Congruent trials were less compatible than the required responses on Incongruent trials because participants had to respond away from or toward two salient stimuli, respectively. However, this is only speculation as it is impossible to separate compatibility from the OS potentially acting as a LM during Incongruent trials during Experiment 1b.

The Incongruent compatibility type advantage for accuracy was also present for response latency. During training participants responded faster on Incongruent trials than on Congruent or Ambiguous trials. At test this advantage for response latency was no longer present between Incongruent and Congruent trials but there was an overall difference in response latency after the data were collapsed across trials using the compatible (X) and incompatible (Y) OS stimuli. Participants responded faster overall during test when OS Y was part of the trial. This result is in the opposite direction of what was originally predicted and is still surprising even when considering the accuracy differences from training and testing.

There are three possible explanations for this finding as in Experiment 1a with the pigeons. The simplest explanation of the faster response time for Incongruent trials is based on differences in the physical distance between the OSs and the goal location. On Incongruent trials, the required movement from OS to the goal location was much shorter than the movement required on Congruent trials because the OS Y was always directly underneath the goal location. Second, because the hidden goal location on Incongruent trials was always directly above OS Y and could be found without waiting for the LM to appear human participants, like pigeons may have responded without waiting for the LM, cancelling out any compatibility effects that were expected. Quick responding from training may have been carried over to testing and explain why participants responded faster on trials using OS Y. However, this quick responding does not seem to be anticipatory because none of the responses occurring during training or testing were faster than 150 ms (Marini, Lani, Nicoletti, & Rubichi, 2011). Lastly, this result is consistent with the above notion that more than one stimulus-response compatibility effect is at work in the current experiment. As explained in the discussion section of Experiment 1a the required response on Congruent trials may actually be less compatible than the required response on Incongruent trials and would explain the lack of a Congruent advantage for latency.

In conclusion, Experiment 1b, demonstrated that human participants, like pigeons, were able to learn an occasion setting task where the correct location was dependent on the spatial position of the OS and LM stimuli. Compatibility did not affect the speed of acquisition of the discrimination or final DR at training or during testing. During test there was less responding on LM alone trials than all other trial types. Consistent with other occasion setting tasks, (e.g., Bonardi & Hall, 1994; Ruprecht et al., 2014; Leising et al., 2015) the most responding at test occurred for the originally trained trial types, followed by the direct transfer trials, and finally the ambiguous transfer trials. However, there was no difference in the magnitude of responding based on compatibility type during training or testing. There was an accuracy advantage for Incongruent trials during training and testing except for the first response at test, where SRC effects should have been observed. Strongest control of responding was demonstrated by OS Y despite LM B and OS X also displaying some control over responding during the transfer test trials. Participants displayed shorter response latencies during training and during testing when data were collapsed across trials utilizing OS Y, the incongruent OS from training. Overall these results seem to indicate that the OS Y from the incongruent stimulus set provided an accuracy and response time advantage for responding, or that highly reliable LM stimuli may negate the effects, positive or negative, of SRC but there are other explanations to consider.

As discussed in Experiment 1a, a configural explanation is possible, but for the reasons presented in the discussion section of Experiment 1a it does seem less likely. Experiment 2 provides additional support for a non-configural approach to learning as participants were able to learn the occasion setting discrimination even though the OS-LM overlap was only 1 s and the OS was not present when the reinforcement was delivered.

As with the pigeons, the data seems to indicate that the effects of compatibility, during this occasion setting task may only be able to influence performance measures that are typically associated with SRC tasks and were either masked, cancelled out by one another, or not strong enough to influence acquisition rate of the discrimination or the OS's ability to transfer conditional control.

Interpretation of the results of Experiment 1 were complicated by the likelihood of the OSs acting as LMs, the influence of proximity of OS Y to the hidden goal, and the potential for the OS and LM to be learned about as a configuration. In Experiment 2 the OS was only present at the start of the trial. After a touch to the OS, it remained on the screen for 1s and then disappeared for the remainder of the trial. This procedural change was expected to solve many of the limitations present in Experiment 1b.

Experiment 2

During Experiment 1b stimulus-response compatibility produced accuracy and response latency differences between Congruent and Incongruent trial types but did not produce any differences in the acquisition rate of the occasion setting discrimination or influence whether the OSs displayed conditional control over responding during transfer tests.

As in Experiment 1b, OSs during Experiment 2 were still part of unique relationships with LM and the location of the hidden goal was dependent on the spatial relationship between the OS and LM. However, the OS during Experiment 2 only remained on the screen for 1 s after the LM appeared, leaving the participants to search for the hidden goal in the presence of only the LM for the remaining duration of the trial. The intent of limiting the overlap time of the OS and LM during occasion setting trials was to reduce the likelihood of the OS stimuli being treated like LM stimuli and to discourage configural learning that may have been present during Experiment 1b.

Experiment 2 did not alter the spatial position of any of the stimuli or the required responses from Experiment 1b. Limiting the overlap time of the OS and LM to 1s should have only decreased the predictive reliability of the OSs because they were no longer on screen every time reinforcement was delivered. Their respective proximity and stability from the hidden goal remain unchanged from Experiment 1b. Decreasing the reliability of OSs should reduce the likelihood of X and Y being treated as LM stimuli and provide a clearer picture of how stimulus-response compatibility influences occasion setting performance.

Experiment 2: Short Duration Proximal Occasion Setting Stimulus - Humans

Method

Participants

Fifty-eight undergraduate psychology students from Texas Christian University (TCU) (*n* = 32) and Arcadia University (AU) (*n* = 26) participated in Experiment 2 as partial fulfillment of psychology course requirements. None of the participants had any previous experience with the experimental design and all participants remained uninformed of the true nature of the study until being debriefed following completion of the study. The entire experiment, including all instructions, training, testing, and debriefing lasted less than 40 minutes. All experiments were conducted in a human cognition lab located at TCU, or in one of the five identical human participant research rooms at AU. All research was conducted according to TCU's Human Participant Ethics Committee as well as an approved IRB protocol from both universities. All experimenters completed training in the ethical treatment of human participants through an online course, "Protecting Human Research Participants".

Apparatus

All training and testing of human participants was conducted using a Hewlett Packard Touchsmart computer (9300 Elite AiO) or a Dell laptop (Latitude E5470). The touchscreen and laptop displayed the stimuli and were capable of recognizing touches and mouse clicks, respectively, as responses.

Touchscreen stimuli

As in Experiment 1b, the visual stimuli used in Experiment 2 fell into one of three stimulus categories: response location, occasion setter, or landmark. The colors, positioning, and counterbalancing of the stimuli were identical to Experiment 1b (see Figure 1). The response locations were a set of eight squares that measured 2 cm^2 and were equally spaced 2.2 cm apart (center to center). The row of response locations was presented 16 cm from the bottom of the screen. An image of a treasure chest that measured 2.25 cm x 3 cm served as the reinforcer for correct responses and appeared at the bottom of the screen, centered between the two middle response locations (4 & 5).

Procedure

Positioning of participant.

Participants were seated in a chair located .6 meters from the computer screen after filling out an informed consent document. To the knowledge of the experimenter this position was maintained by the participant throughout the experiment.

Pretraining 1.

All aspects of Pretraining 1, including the script, during Experiment 2 were identical to Pretraining 1 during Experiment 1b.

Pretraining 2.

All aspects of Pretraining 2, including the script, during Experiment 2 were identical to Pretraining 2 during Experiment 1b.

Occasion setting training.

The script for occasion setting training during Experiment 2 was identical to the script from Experiment 1b.

All details of occasion setting training for Experiment 2 were the same as Experiment 1b, including the same nine distinct trial types from Experiment 1b (see Table 2 and Figure 1) except that after the LM appeared the OS remained on the screen, and overlapped temporally with the LM, for 1 s before disappearing. The LM remained on the screen for 12 s and the removal of the OS allowed the participants to respond in the presence of the LM for the last 11 s of each trial. Responses made to the hidden goal location were rewarded, until stimulus offset (i.e., it is possible that participants received multiple reinforcements per trial), with a 2-s access to the image of an opened treasure chest followed by a 2-s inter-trial interval (ITI) prior to the start of the next trial.

Criterion to advance to test.

The advancement of participants to test during Experiment 2 was identical to Experiment 1b.

Test.

All aspects of the test session during Experiment 2, including the script and the testing trial types (see Table 2), were identical to testing during Experiment 1b except that the occasion setting stimuli overlapped with the LM stimuli for 1 s instead of the full duration of the trial.

Debriefing.

After the testing phase of the experiment was completed the experimenter debriefed each participant and asked a series of questions to help gauge the level of the participant's understanding as well as to reveal the true nature of the experiment (see Appendix A).

Results

Participants with a combined spatial accuracy for the first response on trained trial types at test (XA, YB) that not significantly above chance (.5) were removed from the analysis. This resulted in the data from 22 of the 58 participants being removed. The data from the remaining 36 participants were included in the analysis.

Behavioral Measures and Description of Data Analysis

Prior to running any analyses on the data, a two-way ANOVA was conducted to examine the effects of location (AU vs. TCU) and compatibility level (Congruent, Incongruent, & Ambiguous) on performance for each dependent variable in the experiment. Across all dependent variables there were no statistically significant interactions between location and compatibility level. All additional data analyses were conducted on the combined participant data (AU & TCU) for each of the dependent variables.

All other recorded behavioral measures and data analysis for Experiment 2 were identical to those in Experiment 1b.

Occasion Setting

Training.

Discrimination ratios for each compatibility type (Ambiguous, Congruent, & Incongruent) were compared to chance, .5, to determine at what point during training responding was above chance. Compatibility level did not affect when DRs were above chance. The DRs for Ambiguous, (*M* = .70, *SD* = .32), Congruent (*M* = .67, *SD* = .32), and Incongruent (*M* = .72 *SD* = .30) trials were significantly greater than chance for the first time during third block of training, *ps* < .01. Figure 18 displays occasion setting DR across the eight blocks of training. Occasion setting DR steadily increased across the eight blocks of training (see Figure 18). A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of compatibility (Ambiguous, Congruent, & Incongruent) type on mean DR during the last two blocks of training revealed no effect of compatibility type, *F*(1.59, 74.00) = .78, *p* > .05. A single-sample *t*-test was conducted on the DR for the combined compatibility types to determine if their mean DR was significantly different than .50, chance responding on occasion setting trials, during the last two blocks of training. The combined mean DR (*M* = .85, *SD* = .20), was significantly above chance, *t*(35) = 10.37, *p* < .001.

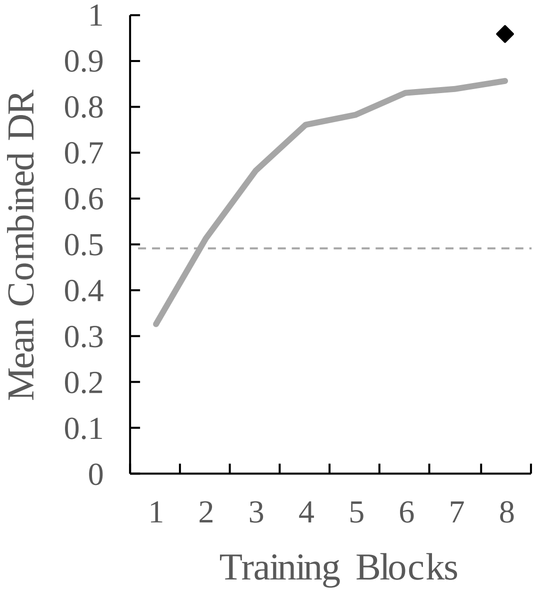


Figure 18. Mean combined discrimination ratio (Ambiguous, Congruent, & Incongruent) across training blocks (9 trials per block) (gray line) and the mean combined discrimination ratio at test (black diamond). The dotted gray line represents chance level of responding.

Testing.

The DR for Congruent and Incongruent trials were compared to one another with a paired-samples *t*-test to determine if there was an effect of compatibility type. The DR for Congruent trials (*M* = .96, *SD* = .09) and Incongruent trials (*M* = .96, *SD* = .11) was not significantly different $t(35) = .568$, $p > .05$. A single-sample *t*-test was conducted on the mean DR for the combined Congruent and Incongruent compatibility types to determine if their mean DR was significantly different than .50 during testing. The combined mean DR ($M = .96$, $SD = .09$) was significantly above chance, $t(35) = 29.75$, $p < .001$. Figure 18 displays the combined mean DR in relation to the blocks of training.

Magnitude of Responding

Testing.

A one-way ANOVA with a Greenhouse-Geisser correction was conducted to determine whether responding differed for any of the LM alone (A, B, C) trial types during test. The analysis did not reveal a significant effect of trial type $F(1.18, 41.17) = 1.06$, $p > .05$, so responding on LM trials was collapsed for analysis. A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of stimulus set (LM, Ambiguous, Congruent, Incongruent, C-Trans, I-Trans, C-Ambig, I-Ambig) on the magnitude of responding revealed a significant effect of compatibility type, $F(2.21, 77.47) = 36.94$, $p < .001$. Planned comparisons revealed that there was significantly less responding during LM ($M = 3.30$, $SD = 8.85$) trials during test compared to all other stimulus sets, $p < .01$. However, none of the other expected differences were significant (e.g., Congruent vs. Incongruent; C-Trans vs. I-Trans). Magnitude was collapsed across test stimulus sets (trained, direct transfer, and ambiguous transfer) and a one-way repeated measures ANOVA revealed a significant effect, $F(2, 70) = 34.57$, $p < .001$. Planned comparisons revealed that participants responded most on trained stimulus sets ($M = 103.69$, $SD = 76.40$), followed by direct transfer stimulus sets ($M = 78.68$, $SD = 68.03$), $p < .01$, and responded the least on ambiguous transfer stimulus sets ($M = 33.47$, $SD = 30.48$), $p < .01$. Magnitude was also collapsed for compatible OSs (i.e., XA, XB, &

XC) and incompatible OSs (i.e., YB YA, & YC) at test. A paired-samples *t*-test revealed no significant differences in responding during incompatible (*M* = 74.93, *SD* = 56.98) or compatible (*M* = 69.97, *SD* = 52.67) trials during test, *t* (35) = -1.86, *p* > *.05.* Figure 19 displays the mean magnitude of responding for each compatibility type during testing.

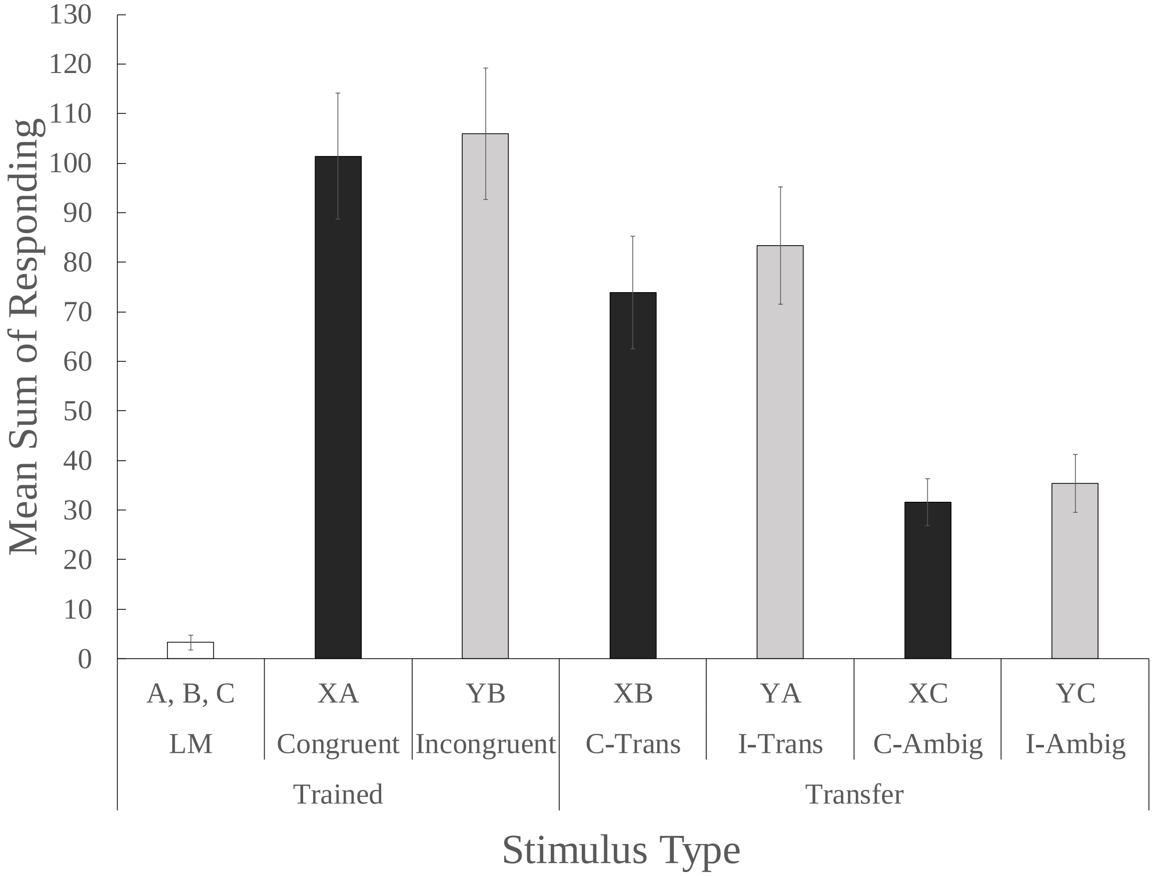


Figure 19. Magnitude of responding during test. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled "Trained". Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled "Transfer". The letters "C" and "I" represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., "I" corresponds with Incongruent). "Trans" indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS

from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. Responding on LM alone trials was collapsed across trial types (A-, B-, C-). Error bars represent standard errors of the means**.**

Accuracy and Difference Score

Training.

A one-way repeated measures ANOVA was conducted to compare the effect of compatibility type (Ambiguous, Congruent, & Incongruent) on response accuracy for the first response to one of the eight response locations after the OS had been touched during the last two blocks of training. The results demonstrated a significant effect of compatibility type, $F(2, 70) = 19.26$, $p < .001$. Planned comparisons demonstrated that participants were significantly more accurate on Incongruent trials ($M = .80$, $SD = .27$) than on Congruent ($M = .67$, $SD = .33$), or Ambiguous ($M = .49$, $SD = .18$) trials, $p < .05$. Participants were also significantly more accurate on Congruent ($M = .67$, $SD = .33$), than Ambiguous ($M = .49$, $SD = .18$) trials, $p < .01$. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracies were above chance for Congruent and Incongruent trials, $ts(35) > 3.06$, $ps < .01$, but not Ambiguous trials, $t(35) = -.39$, $p > .05$. Figure 20 displays the mean response accuracies for each compatibility type during the last two block of training.

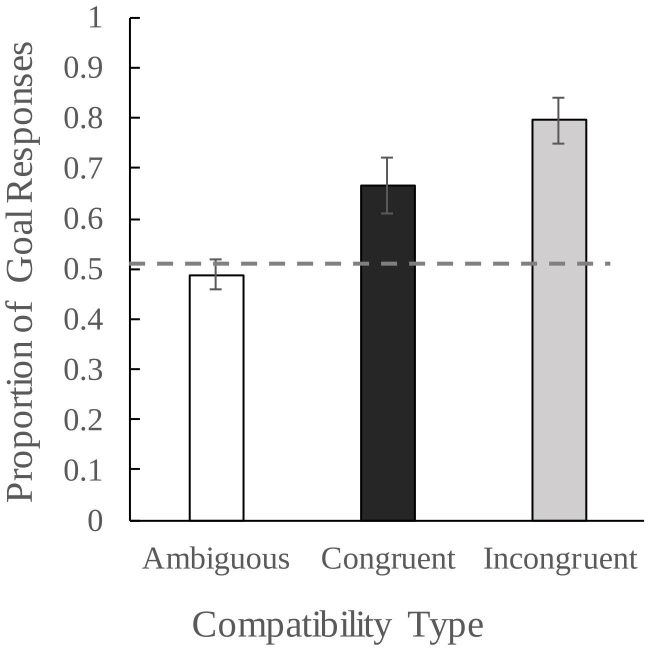


Figure 20. Mean proportion of responses occurring at the correct goal location for each compatibility type during the last two blocks of training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means.

Testing.

First response.

A paired-samples *t*-test was conducted on the mean of the first response to one of the eight response locations after the OS had been touched to determine if participants responded more accurately during one of the training compatibility types (i.e., Congruent & Incongruent) than the other at test. Participants were significantly more accurate on Incongruent trials (M = .90, SD = .17) than on Congruent trials (M = .81, SD = .21) at test, $t(35) = -3.95$, $p < .05$. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Congruent and Incongruent trials, $ts(35) > 8.92$, $ps < .001$.

As previously stated a difference score was calculated for transfer trials at test to get a measure of spatial control. The difference score for each transfer trial type (XB, YA, XC, YC) was compared to zero with a single-sample *t*-test. None of the transfer trials were different than zero. Figure 21 displays the mean first response accuracies for each compatibility type and the difference score for transfer trials during test.

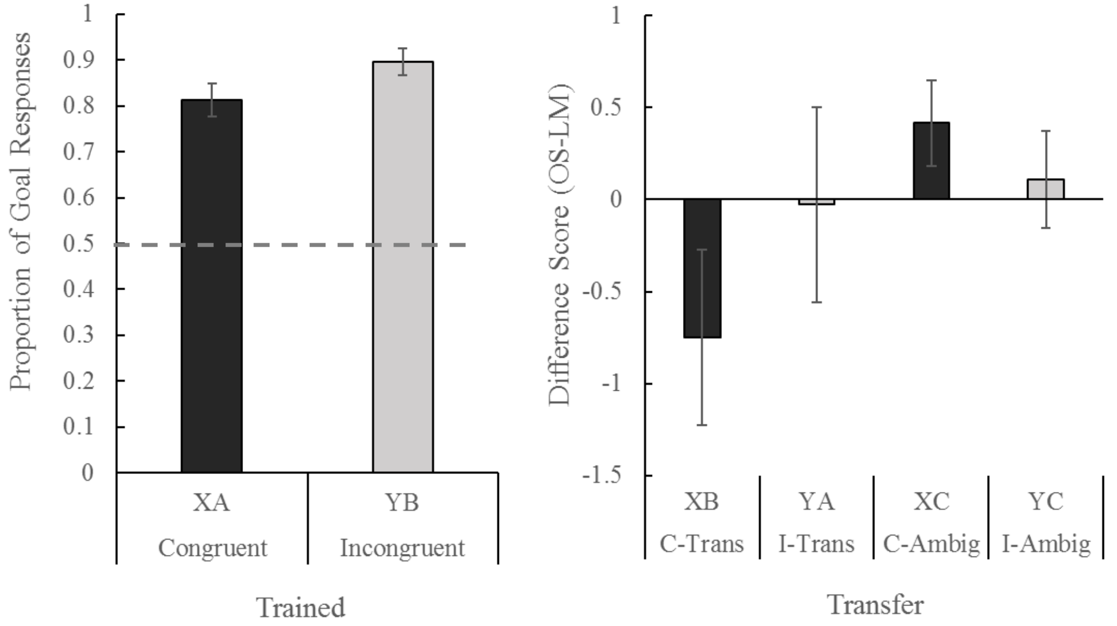


Figure 21. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for first response only. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled "Trained". Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled "Transfer". The letters "C" and "I" represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., "I" corresponds with Incongruent). "Trans" indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. "Ambig" indicates a transfer trial where one of the training OSs

was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means**.**

All responses.

A paired-samples *t*-test was conducted on the mean of all responses to one of the eight response locations after the OS had been touched to determine if participants responded more accurately during one of the training compatibility types (i.e., Congruent & Incongruent) than the other at test. Participants were not more accurate on Incongruent trials (M = .88, SD = .19) than on Congruent (M = .82, SD = .25) at test, $t(35) = -1.79$, $p > .05$. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Congruent and Incongruent trials, $ts(35) > 7.66$, $ps < .001$.

As previously stated a difference score was calculated for transfer trials at test to get a measure of spatial control. The difference score for each transfer trial type (XB, YA, XC, YC) was compared to zero with a single-sample *t*-test. Only transfer trial XC (M = 16.22, SD = 31.17) was significantly different than zero, $t(35) = 3.12$, $p <.01$. Figure 22 displays the mean response accuracies for each compatibility type and the difference score for transfer trials during test for all responses.

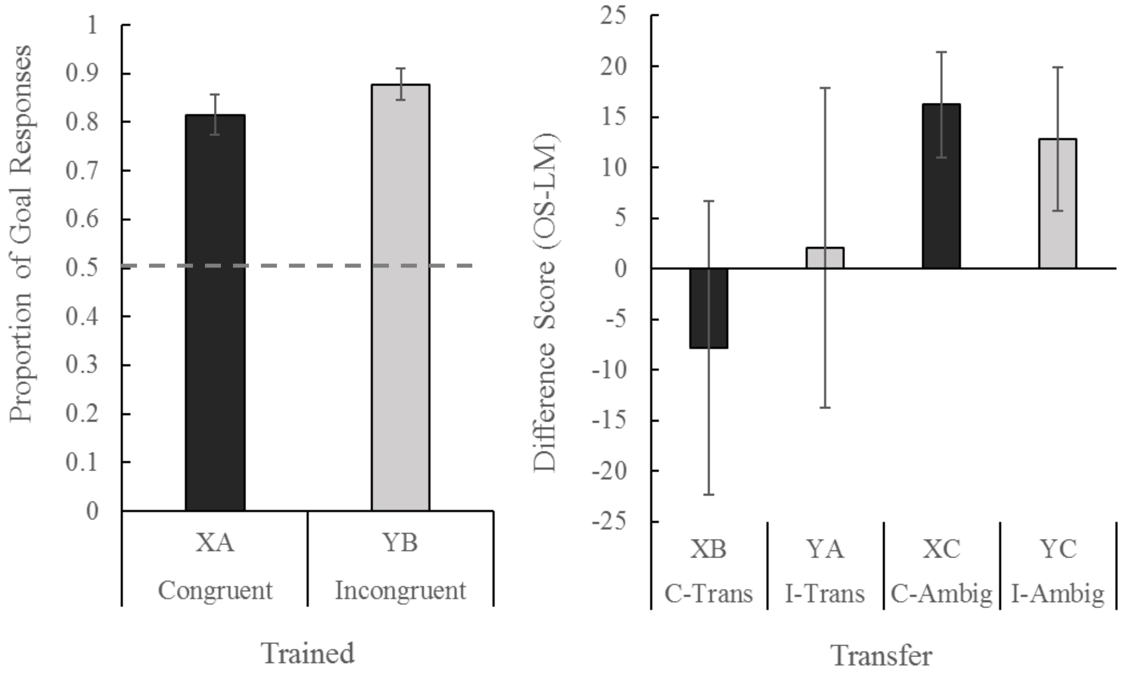


Figure 22. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for all responses during test. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled “Trained”. Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled “Transfer”. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., “I” corresponds with Incongruent). “Trans” indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means**.**

Response Latency

All statistical analyses for response latency were conducted on the log transformed data (Lg10) and raw data were used for the figures and descriptive statistics.

Training.

A one-way repeated measures ANOVA with a Greenhouse-Geisser correction was conducted to compare the effect of compatibility type (Ambiguous, Congruent, Incongruent) on the response latency during the last two blocks of training. There was no significant effect of compatibility type, $F(1.96, 68.56) = .158$, $p > .05$. Figure 23 displays the raw data mean response latencies for the different compatibility types at test.

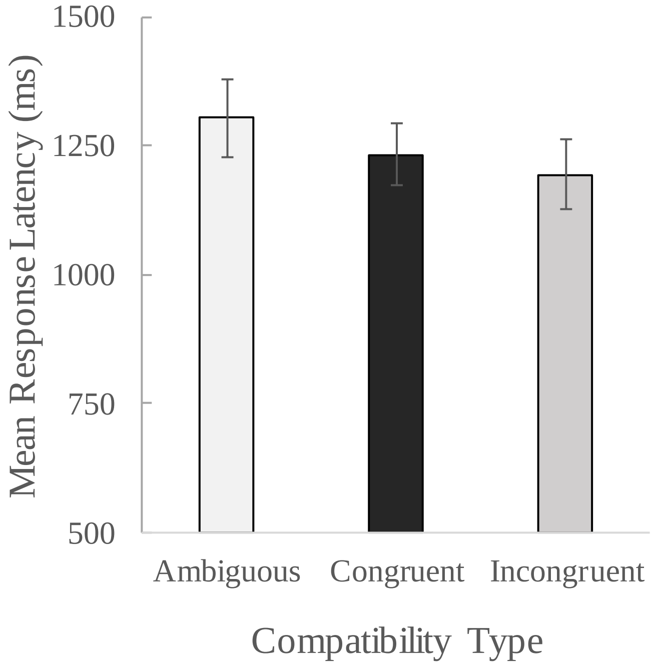


Figure 23. Response latency in ms for each of the compatibility types during the last two blocks of training. Error bars represent standard errors of the means**.**

Testing.

A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of compatibility type (Ambiguous, Congruent, & Incongruent) on the latency to respond revealed a significant effect of compatibility type at test, $F(2.62, 68.04) = 3.22$, $p < .05$. However, planned comparisons failed to reveal any significant differences.

We expected to see a difference in response latencies at test, especially for the originally trained trial types (i.e., Congruent & Incongruent). A paired-samples *t*-test \conducted on the mean response latencies for Congruent and Incongruent trials at test revealed no significant difference in response latency for Congruent trials ($M = 1407.57$, $SD = 61.00$) and Incongruent ($M = 1363.24$, $SD = 66.20$) at test, $t(32) = 1.26$, $p > .05$. Response data were collapsed for compatible OSs (i.e., XA, XB, & XC) and incompatible OSs (i.e., YB YA, & YC) at test. A paired-samples *t*-test revealed that there was no significant difference in response latency for compatible trials ($M = 1488.56$, $SD = 319.20$) and incompatible ($M = 1455.08$, $SD = 415.29$) trials at test, $t(34) = 1.67$, $p > .05$. Figure 24 displays the raw data mean response latencies for the different compatibility types during training.

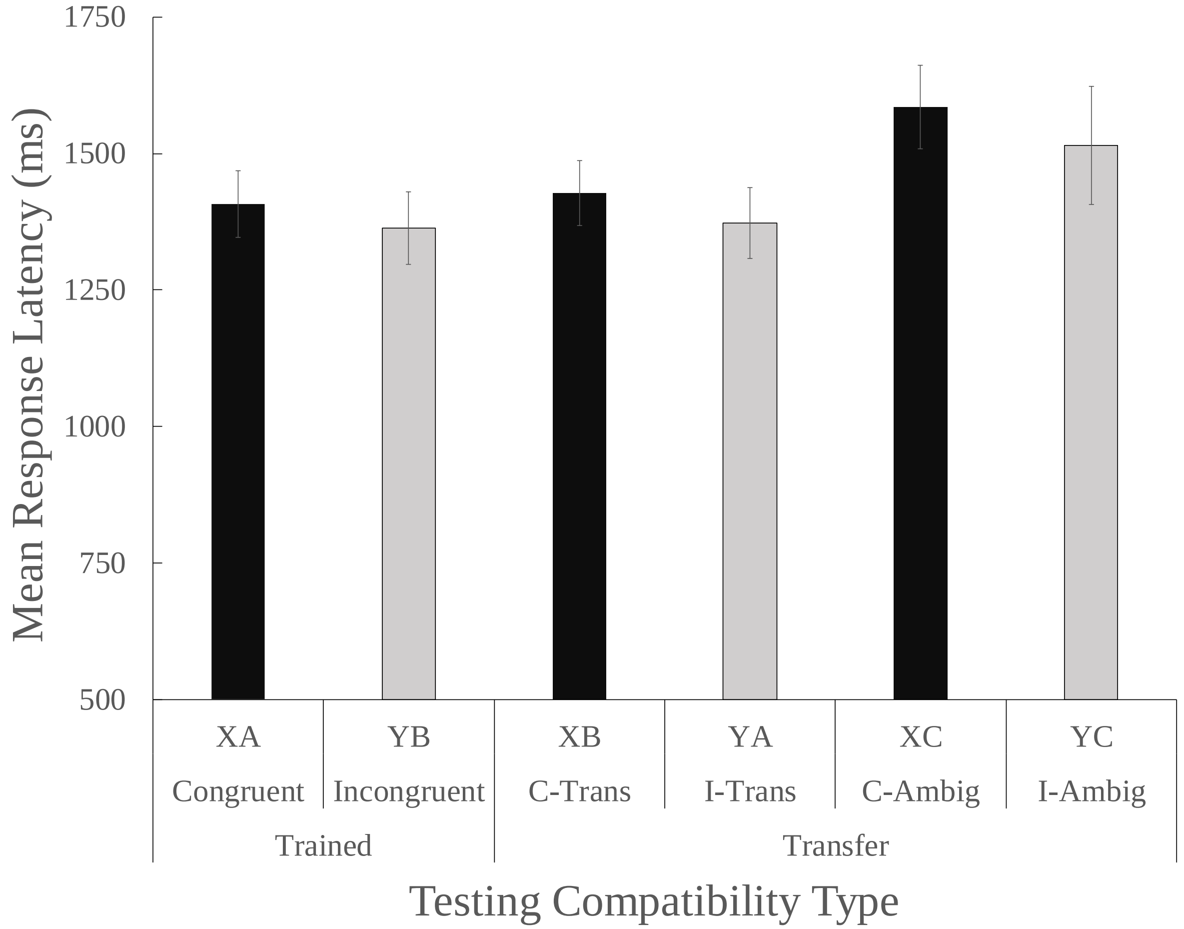


Figure 24. Mean response latency in ms for each of the compatibility types during testing. Error bars represent standard errors of the means**.**

Discussion

Landmark and occasion setting stimuli in Experiment 2 were designed to be reliable predictors of the hidden goal during occasion setting trials but spatially unstable predictors of the location of the hidden goal on their own as in Experiment 1b. The compatibility types, stimuli, and responses required for each of the compatibility types was identical to Experiment 1b. However, in Experiment 2, the OS remained on the screen for only 1 s after the LM was touched. The purpose of this manipulation was to discourage configural learning, and decrease the reliability of the OSs thereby reducing their effectiveness as LMs. The results indicated that compatibility differences did not affect the ability of participants to learn the occasion setting discrimination, the OSs' ability to gain conditional control over responding, or produce response latency differences, but compatibility did produce a response accuracy advantage for Incongruent trials.

With respect to rate of acquisition of the discrimination, as in Experiment 1b, compatibility did not produce a difference. Like Experiment 1b, there were also no significant differences in DR by the end of training for any of the compatibility types (Congruent, Incongruent, or Ambiguous), or during testing for the Incongruent and Congruent trial types. This indicates that participants responded significantly more during occasion setting trials than during the LM alone despite limiting the overlap between the OS and LM to 1 s.

As in Experiment 1b, the mean magnitude of responding was used to evaluate any differences between stimuli, but only for testing trial types. Participants responded less than they did on the originally trained trial types (XA, YB) when the spatial information from the stimuli conflicted during transfer trials (e.g., XB, YA) and responded the least when the OS X or Y from training was placed in a novel pairing with the LM C (the least reliable LM from training). These results replicate the finding from Experiment 1b and previous occasion setting tasks, with participants responding more on trained occasion setting trial types (XA, YB) at test than during the direct transfer trials (XB, YA) (Cleland et al., 2017). This finding is consistent with the development of some degree of acquired equivalence between A and B, which resulted in more transfer on XB and YA trials than on XC or YC trials. Level of compatibility did not affect the ability of the OSs to control how much participants responded during the novel transfer tests.

Another result that replicates a finding from Experiment 1b was that, contrary to the original hypothesis, there was an accuracy advantage for Incongruent trials compared to

Congruent or Ambiguous trials during training. In addition to the findings from Experiment 1b, there was an accuracy advantage for Congruent trials compared to Ambiguous trials. This result makes sense because limiting the overlap between the OS and LM during occasion setting trials should have further decreased participants' reliance on the OS when making a response. Once reinforcement was earned on a given trial, even on Ambiguous trials the relationship between OS and LM could be used to continue to find the hidden goal. However, if the OS was removed, as in Experiment 2, then the task becomes even more difficult on Ambiguous trials because the OS and LM have occurred in four different relationships with a hidden goal. The result is decreased accuracy on Ambiguous trials on both the first response and all responses together. The accuracy advantage on Incongruent trials compared to Congruent trials during training persisted into testing, but only when looking at the first response data. This is different than Experiment 1b, where the accuracy advantage was absent from first response and present when all of the responses were included. This difference is likely due to the OS/ LM overlap difference between the experiments. Participants continuing to respond after the first response in Experiment 2 had to do so without the presence of the OS. Accuracy was higher when analyzing all responses compared to the first response in Experiment 1, whereas, overall accuracy was lower for all responses compared to first responses during Experiment 2. There was no difference in accuracy across Experiment 1b and 2 for either of the compatibility types but participants were more accurate during Experiment 1b than Experiment 2 for all responses, indicating that without the presence of the OS, accuracy for all responses suffered during Experiment 2.

The accuracy results from Experiment 2 are consistent with Experiment 1b, but in the opposite direction of the original hypothesis regarding congruency. As in Experiment 1b there are at least two explanations for why Incongruent trials produced more accurate responding than

Congruent trials. First, although we reduced OS-LM overlap to decrease the likelihood of the OS being treated as a LM, due to proximity and reliability participants may still have treated the OS stimuli as LMs. Each individual stimulus was assigned a predictive weight based on its ability to direct responding to the correct goal location on its own. Occasion setter Y was assigned a predictive weight of .9 because it was extremely close to the goal, stable, and the only stimulus capable of guiding participants to the hidden goal location without information from any other stimuli. LMs A and B were each assigned predictive weights of .6 because they were close to the goal location but on their own they were only able to narrow down participants responding to two possible response locations. Participants needed information from an OS stimulus, to find the hidden goal with absolute certainty. Occasion setter X was assigned a predictive weight of .3 because it was far away from the goal location and on its own was only able to narrow down participant responding to two possible response locations. LM C was assigned a predictive weight of .2 because it narrowed down participant responding to two possible response locations but even with the help of an OS participants could only narrow down their responding to two possible response locations. Predictions on the ability of each stimulus to gain conditional control over where participants would respond during the transfer test can be seen in Figure 25.

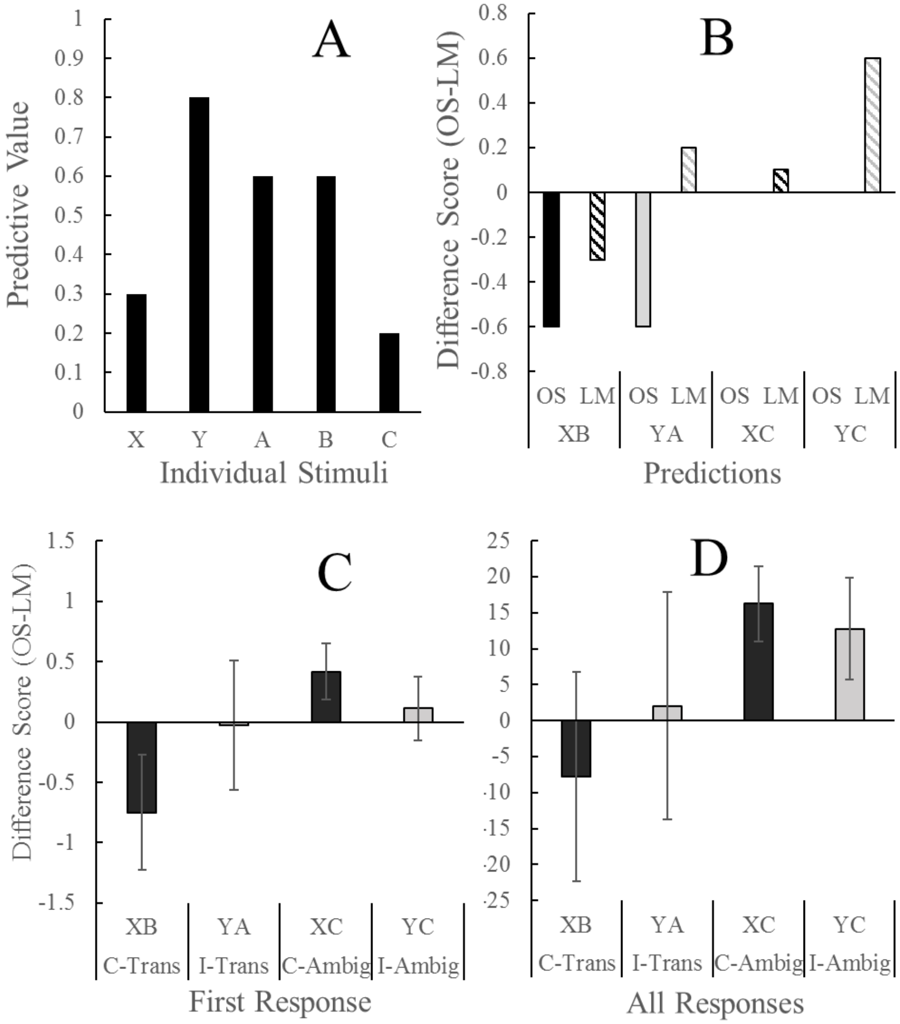


Figure 25. Displays conditional control of spatial responding during the transfer test trials. Panel A displays the predictive value each stimulus was given based on the ability of that stimulus to direct participants to the correct goal location on its own during training. Panel B displays the predictions made for transfer of conditional control assuming the OSs during training were treated as OSs (OS) and assuming the OSs, were acting as LM stimuli. The prediction panel (B) of the figure was the result of combining the predictive weights of each stimulus and graphing resulting difference scores. Panels C and D display the spatial control data as a difference score based on OS directed responding – Other directed responding for the first response and all responses, respectively, during the transfer tests.

Comparing these predictions to the actual data obtained during testing (see Figure 25) indicates that participants treated OS Y like a LM and OS X more like an OS, and that simply limiting the duration of the OS during the trial was not sufficient to prevent OS Y from being treated as a LM. All of the transfer trials should have once again generated uncertainty about the location of the hidden goal and forced participants to rely on what was learned about each of the stimuli during training (Cheng et al., 2007). Spatial control should be based on how predictive (reliable, stable, and proximal) each stimulus was during training, which determine the weights assigned to each stimulus (see Figure 25). In Experiment 2, OS Y was made less reliable by providing the opportunity for reinforcement in the presence of LM B after Y had disappeared. Y remained a stable and proximal cue for the hidden goal when present. As predicted, limiting the OS duration seemed to weaken the predictive value of OS Y on YC trials. On the other hand, despite the reduced reliability of OS X, it was still able to control responding on XC trials indicating that at the very least it must be acting in part, as on OS. In Experiment 1b, overshadowing was also mentioned as a potential mechanism for reduced control by an OS or LM.

The closer proximity of OS Y, LM A, and LM B to the goal location than OS X was still present in Experiment 2. Although OS Y and LM B were equally proximal and stable with respect to the location of the goal, the shortened duration of OS Y when reinforcement was available during occasion setting trials should have decreased the reliability of the OS stimulus while simultaneously increasing the reliability of the LM stimulus (i.e., by earning reinforcement in the presence of the LM alone). This likely made A and B more reliable cues that could more effectively overshadow X and Y. However, the results do not support this conclusion because neither LM B or A were able to gain spatial control during their respective transfer trials. Only

X was able to gain spatial control on XC trials, which suggests X continued to be an effective LM or OS. The properties of X made for a weak LM (less proximal to the goal than Y, A, or B), but match what would be expected if X was functioning as an OS. Consistent with previous research (Leising et al., 2015; Cleland et al., 2017), OS stimuli have been shown to exert spatial control over responding only when paired with a LM (e.g., C) that does not provide stable spatial information regarding the goal location.

Limiting the OS duration helped OSs assume a more traditional OS role but did not prevent OS Y from being treated as a LM. The short OS-LM overlap also did nothing to change the fact that as in Experiment 1b, requiring a response to the right of LM A on an XA+ trials may have been more incompatible than requiring a response to the left of LM B on an Y+B trials because participants had to respond away from and toward two salient stimuli to find the goal, respectively. The stimulus-response set on Incongruent trials may actually have been more congruent despite the designed directional SRC. However, this is only speculation as Experiment 2 was unable to separate compatibility effects from the OS stimulus potentially acting as LM.

Whereas the Incongruent compatibility type provided a response accuracy advantage, there was no difference in the response latencies for the different compatibility types for training or testing. This is inconsistent with the results of Experiment 1b where Incongruent compatibility types produced a response latency advantage, as well as SRC research. Previous research has demonstrated that response latency effects occur independently of the ability to correctly identify or execute the correct response (Simon & Rudell, 1967; Guiard, 1983; Simon & Bernbaum, 1990). Incompatibility should still produce slower response latencies in the current experiment even if participants can inhibit automatic responding and respond accurately on Incongruent trials.

The same rationale and three explanations for why Incongruent trials produced faster response latencies during Experiment 1b can be applied to the lack of any differences observed in Experiment 2. The physical distance between the OSs and the predicted hidden goal was greater on Congruent than Incongruent trials. Also, the goal location on Incongruent trials was directly above OS Y and could be found without waiting for the LM to appear. These factors support quick responses on Incongruent trials, and may have negated the potential effects of incompatibility. The mean response latency for all of the compatibility types indicates that the majority of first responses occurred after 1250 ms, which is after the OS had disappeared. This makes the explanation in terms of anticipatory responding less likely. Lastly, this result is consistent with the idea that the stimuli involved in SRC may be the OS and LM together, rather than the LM relative to fixation on the OS, as expected. The designed stimulus-response requirements on Congruent trials may actually be less compatible.

In conclusion, Experiment 2 demonstrated that participants were able to learn an occasion setting task where the correct location was dependent on the spatial position of the LM relative to the OS even when the OS and LM overlapped on the screen for only 1 s (out of 12 s) during each trial. As in Experiment 1b, compatibility effects did not affect the speed of acquisition or final DR at training or during testing. Consistent with previous occasion setting literature (e.g., Bonardi & Hall, 1994; Ruprecht et al., 2014; Leising et al., 2015) the most responding at test occurred for the originally trained trial types, followed by the direct transfer trials, and finally the ambiguous transfer trials. However, there was no difference in the magnitude of responding based on compatibility type during training or testing. There was an accuracy advantage for

Incongruent trials during training and testing, but only for the first response at test. This is likely due to the fact that the OS and the LM temporally overlapped for 1 s, making additional responses later during a trial generally less accurate. Without OS Y during subsequent responses during the trial Incongruent accuracy suffers, indicating that Y is still being relied on to find the goal location in Experiment 2. Occasion setter X, but not OS Y, was able to control the location of responding during transfer testing, but only when paired with LM C. The reduction in spatial control for OS Y is likely due to the weakened predictive value of OS Y acting as a LM and increased reliability of the true LM stimuli. Occasion setter X, acting more like an OS than Y did not lose the ability to control responding. Unlike Experiment 1b, there was no difference in response latencies for the different compatibility types during training or testing. The results from Experiment 2 demonstrated that limiting the OS and LM overlap reduced the predictive value of OS Y and eliminated the Incongruent accuracy advantage for all responses at test and the response latency advantage from Experiment 1b. However, Experiment 2 added additional evidence to support the conclusion from the first human and pigeon experiment that the SRC effects, at least in the current spatial occasion setting experiment, did not influence performance measures typically associated with occasion setting.

The close proximity of the OS stimuli to the hidden goal and the LM was only partially addressed by limiting the time that the OS and LM stimuli overlapped on occasion setting trials during Experiment 2. Experiment 3 attempted to gain a clearer understanding of how SRC effects can influence learning and performance during a spatial occasion setting task. Experiment 2 removed the trial-long overlap between the OS and LM from Experiment 1b but the OS and LM stimuli were still very close in proximity and OS Y was still directly underneath the location of the hidden goal.

On occasion setting trials during Experiment 2 the OS was still close to the goal location especially on YB trials where Y was directly underneath the goal. Experiment 3 attempted to address the limitation of spatial proximity potentially masking compatibility effects by presenting the OS stimuli on the edges of the response array while holding constant the duration of the OS-LM overlap from Experiment 2. This manipulation should reduce the influence of stimulus proximity to the goal location which may have been masking compatibility effects and further discourage the potential the stimuli were learned about as a configuration.

Experiment 3

There were fewer compatibility differences between Congruent and Incongruent trials during Experiment 2, potentially due to the decreased overlap between the OS and LM during occasion setting trials. The different levels of compatibility did not produce any differences in the ability of participants to learn the occasion setting discrimination, the OSs ability to gain conditional control over responding, or in response latency. There was a response accuracy advantage for Incongruent trials, which was consistent with the findings of Experiment 1b.

Experiment 3 addressed the limitations of Experiment 1 and 2. Instead of positioning the OS and LM stimuli close to each other, as in Experiment 1b and 2, the OS was always presented under response locations 1 or 8 (the farthest left and right response locations respectively) and never under the goal location. This lateralized positioning of the OS should have reduced the chance that the OS was treated as a LM because it was no longer close to the location of the hidden goal. Positioning the OS on the edges of the display and away from the LM should have further decreased the chance of the OS and LM stimuli being learned as a configuration. It also should have also neutralized the possible effect in Experiments 1b and 2 of the physical distance between a touch to the OS to display the LM and a touch to the required goal location response.

Experiment 3 provided the clearest evaluation of SRC effects due to the congruency between the spatial relationship of the OS and LM and the required response on a spatial occasion setting task.

Experiment 3: Short Duration Distal Occasion Setting Stimulus - Humans

Method

Participants

Sixty undergraduate psychology students from Texas Christian University (TCU) (*n* = 34) and Arcadia University (AU) (*n* = 26) participated in Experiment 3 as partial fulfillment of psychology course requirements. None of the participants had any previous experience with the experimental design and all participants remained uninformed of the true nature of the study until being debriefed following completion of the study. The entire experiment, including all instructions, training, testing, and debriefing lasted less than 40 minutes. All experiments were conducted in a human cognition lab located at TCU, or in one of the five identical human participant research rooms at AU. All research was conducted according to TCU's Human Participant Ethics Committee as well as an approved IRB protocol from both universities. All experimenters completed training in the ethical treatment of human participants through an online course, "Protecting Human Research Participants".

Apparatus

All training and testing of human participants was conducted using a Hewlett Packard Touchsmart computer (9300 Elite AiO) or a Dell laptop (Latitude E5470). The touchscreen and laptop displayed the stimuli and were capable of recognizing touches and mouse clicks, respectively, as responses.

Touchscreen stimuli

As in Experiment 2, the visual stimuli used in Experiment 3 fell into one of three stimulus categories: response location, occasion setter, or landmark. The colors and counterbalancing of the stimuli were identical to Experiment 2 (see Figure 26) but the OS stimuli could only appear beneath Response Location 1 or 8. The response locations were a set of eight squares that measured 2 cm^2 and were equally spaced 2.2 cm apart (center to center). The row of response locations was presented 16 cm from the bottom of the screen. An image of a treasure chest that measured 2.25 cm x 3 cm served as the reinforcer for correct responses and appeared at the bottom of the screen, centered between the two middle response locations (4 & 5).

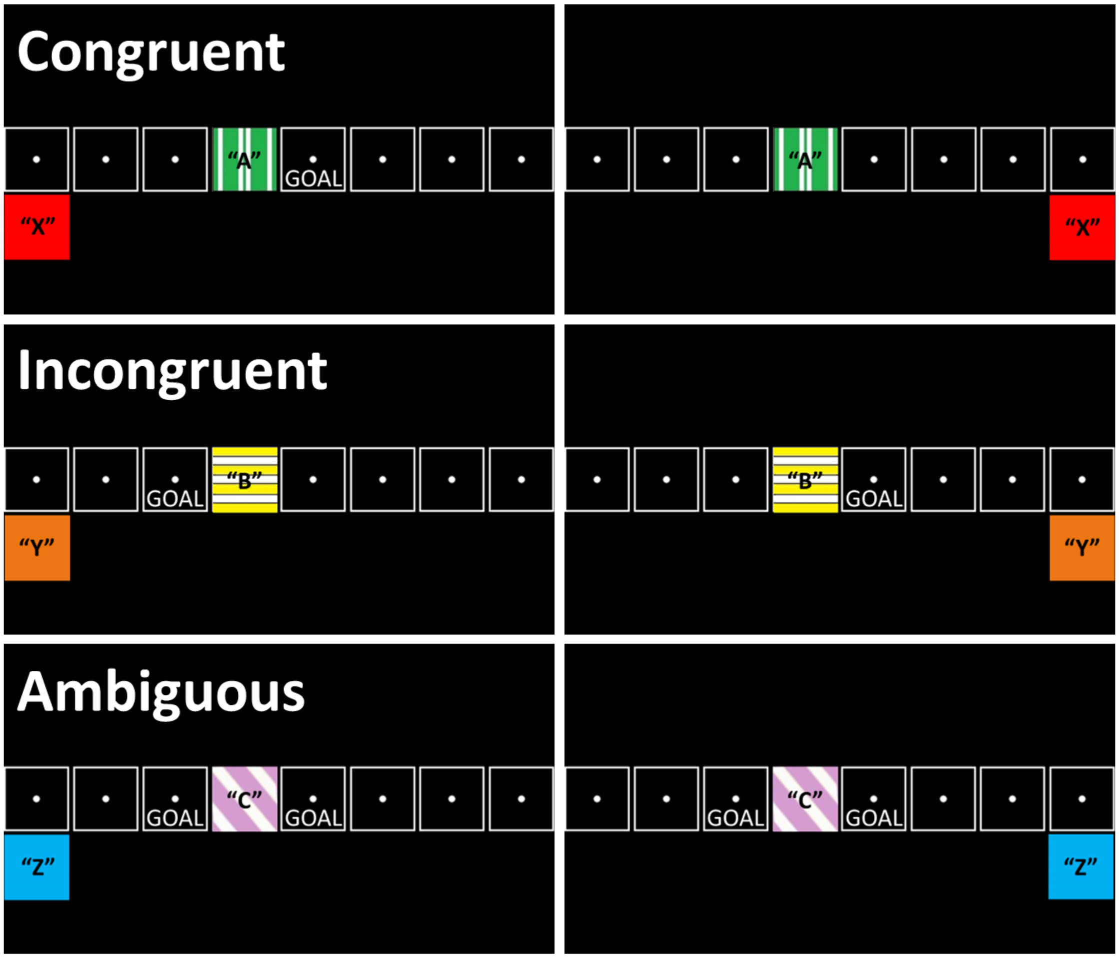


Figure 26. Displays the combinations of the OSs and LMs that made up the occasions setting training trial types for Experiment 3. The OSs were three uniquely colored squares, X (red), Y (orange), and Z (cerulean) and the LMs were three uniquely colored and patterned squares A (green with vertical white lines), B (yellow with horizontal white lines), C (pink with diagonal white lines). The word "GOAL" in a response box indicates the location of the hidden goal on each trial type relative to the positioning of the OS and LM. When the "GOAL" is present on both sides of the LM there was 50% chance of either side hiding the goal each trial. The trial types are categorized into Congruent, Incongruent, and Ambiguous based on the response requirement (i.e., left or right of the LM). Colors of LMs and OSs were counterbalanced across participants. LM alone (A-, B-, & C-) trials are not shown.

Procedure

Positioning of participant.

Participants were seated in a chair located .6 meters from the computer screen after filling out an informed consent document. To the knowledge of the experimenter this position was maintained by the participant throughout the experiment.

Pretraining 1.

All aspects of Pretraining 1, including the script, during Experiment 3 were identical to Pretraining 1 during Experiments 1b and 2.

Pretraining 2.

All aspects of Pretraining 2, including the script, during Experiment 3 were identical to Pretraining 2 during Experiments 1b and 2.

Occasion setting training.

The script for occasion setting training during Experiment 3 was identical to the script from Experiments 1b and 2.

All details of occasion setting training for Experiment 3 were the same as Experiments 1b and 2, including the same nine distinct trial types from Experiment 1b (see Table 2 and Figure 26) except that the occasion setting stimuli were only presented beneath Response Locations 1 or 8. The OS and LM still overlapped for 1 s during each trial. The LM remained on the screen for 12 s and the removal of the OS allowed the participants to respond in the presence of the LM for the last 11 s of each trial. Responses made to the hidden goal location were rewarded, until stimulus offset (i.e., it is possible that participants received multiple reinforcements per trial), with a 2-s access to the image of an opened treasure chest followed by a 2-s inter-trial interval (ITI) prior to the start of the next trial.

Criterion to advance to test.

The advancement of participants to test during Experiment 3 was identical to Experiments 1b and 2.

Test.

All aspects of the test session during Experiment 3, including the script and the testing trial types (see Table 2), were identical to testing during Experiments1b and 2, except that the occasion setting stimuli were presented under only Response Locations 1 or 8. The OS and LM still overlapped for 1 s during the test trials.

Debriefing.

After the testing phase of the experiment was completed the experimenter debriefed each participant and asked a series of questions to help gauge the level of the participant's understanding as well as to reveal the true nature of the experiment (see Appendix A).

Results

Participants with a combined spatial accuracy for the first response on trained trial types at test (XA, YB) that was not significantly above chance (.5) were removed from the analysis. This resulted in the data from 24 of the 60 participants being removed. The data from the remaining 36 participants were included in the analysis.

Behavioral Measures and Description of Data Analysis

Prior to running any analyses on the data, a two-way ANOVA was conducted to examine the effects of location (AU vs. TCU) and compatibility level (Congruent, Incongruent, & Ambiguous) on performance for each dependent variable in the experiment. Across all dependent variables there were no statistically significant interactions between location and compatibility level. All additional data analyses were conducted on the combined participant data (AU & TCU) for each of the dependent variables.

All other recorded behavioral measures and data analysis for Experiment 3 were identical to those in Experiment 2.

Occasion Setting

Training.

Discrimination ratios for each compatibility type (Ambiguous, Congruent, & Incongruent) were compared to chance, .5, to determine at what point during training responding was above chance. Compatibility level did not affect when DRs were above chance. The DRs for Ambiguous, (*M* = .65, *SD* = .32), Congruent (*M* = .63, *SD* = .37), and Incongruent (*M* = .65 *SD* = .32) trials were significantly greater than chance for the first time during third block of training, *ps* < .05. Figure 27 displays the occasion setting DR steadily increasing across the eight blocks of training. A one-way repeated measures ANOVA with a Greenhouse-Geisser correction conducted to compare the effect of compatibility (Ambiguous, Congruent, & Incongruent) type on mean DR during the last two blocks of training revealed no effect of compatibility type, *F*(1.45, 70) = 1.19, *p* > .05. A single-sample *t*-test was conducted on the DR for the combined compatibility types to determine if their mean DR was significantly different than .50, chance responding on occasion setting trials, during the last two blocks of training. The combined mean DR (*M* = .83, *SD* = .23), was significantly above chance, *t*(35) = 8.68, *p* < .001.

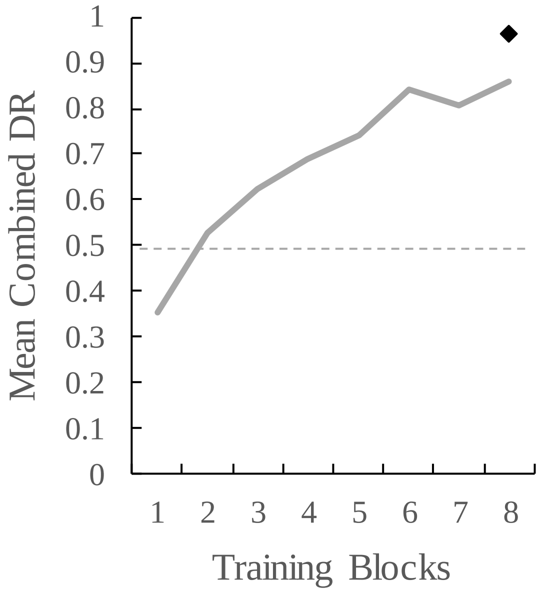


*Figure 27***.** Mean combined discrimination ratio (Ambiguous, Congruent, & Incongruent) across training blocks (9 trials per block) (gray line) and the mean combined discrimination ratio at test (black diamond). The dotted gray line represents chance level of responding.

Testing.

The DR for Congruent and Incongruent trials were compared to one another with a paired-samples *t*-test to determine if there was an effect of compatibility type. The DR for Congruent trials (*M* = .95, *SD* = .14) and Incongruent trials (*M* = .97, *SD* = .08) was not significantly different, *t*(34) = -.783, *p* > .05. A single-sample *t*-test was conducted on the mean DR for the combined Congruent and Incongruent compatibility types to determine if their mean DR was significantly different than .50 during testing. The combined mean DR (*M* = .96, *SD* = .09) was significantly above chance, *t*(34) = 31.50, *p* < .001. Figure 27 displays the combined mean DR in relation to the blocks of training.

Magnitude of Responding

Testing.

A one-way ANOVA with a Greenhouse-Geisser correction conducted to determine whether responding differed for any of the LM alone (A, B, and C) trial types during test revealed no significant effect of trial type $F(1.11, 38.98) = .20$, $p > .05$, so responding on LM trials was collapsed for analysis. A one-way repeated measures ANOVA was conducted to compare the effect of stimulus set (LM, Ambiguous, Congruent, Incongruent, C-Trans, I-Trans, C-Ambig, I-Ambig) on the magnitude of responding revealed a significant effect of stimulus set, $F(1.59, 50.85) = 27.28$, $p < .001$. Planned comparisons revealed that there was significantly less responding during LM ($M = 9.37$, $SD = 29.77$) trials during test compared to all other stimulus sets, $p < .01$. However, none of the other expected differences were significant (e.g., Congruent vs. Incongruent; C-Trans vs. I-Trans). Magnitude was collapsed across test stimulus sets (trained, direct transfer, and ambiguous transfer) and a one-way repeated measures ANOVA with a Greenhouse-Geisser correction revealed a significant effect, $F(1.26, 43.94) = 35.87$, $p < .001$. Planned comparisons revealed that participants responded most on trained stimulus sets ($M = 90.38$, $SD = 74.36$), followed by direct transfer stimulus sets ($M = 78.82$, $SD = 72.46$), $p <. 01$, and responded the least on ambiguous transfer stimulus sets ($M = 35.89$, $SD = 38.00$), $p < .01$. Magnitude was also collapsed for compatible OSs (i.e., XA, XB, & XC) and incompatible OSs (i.e., YB YA, & YC) at test. A paired-samples *t*-test revealed no significant differences in responding during compatible ($M = 70.92$, $SD = 61.94$) or incompatible ($M = 67.15$, $SD = 57.56$) trials during test, $t\ (35) = 1.62$, $p > .05$. Figure 28 displays the mean magnitude of responding for each compatibility type during testing.

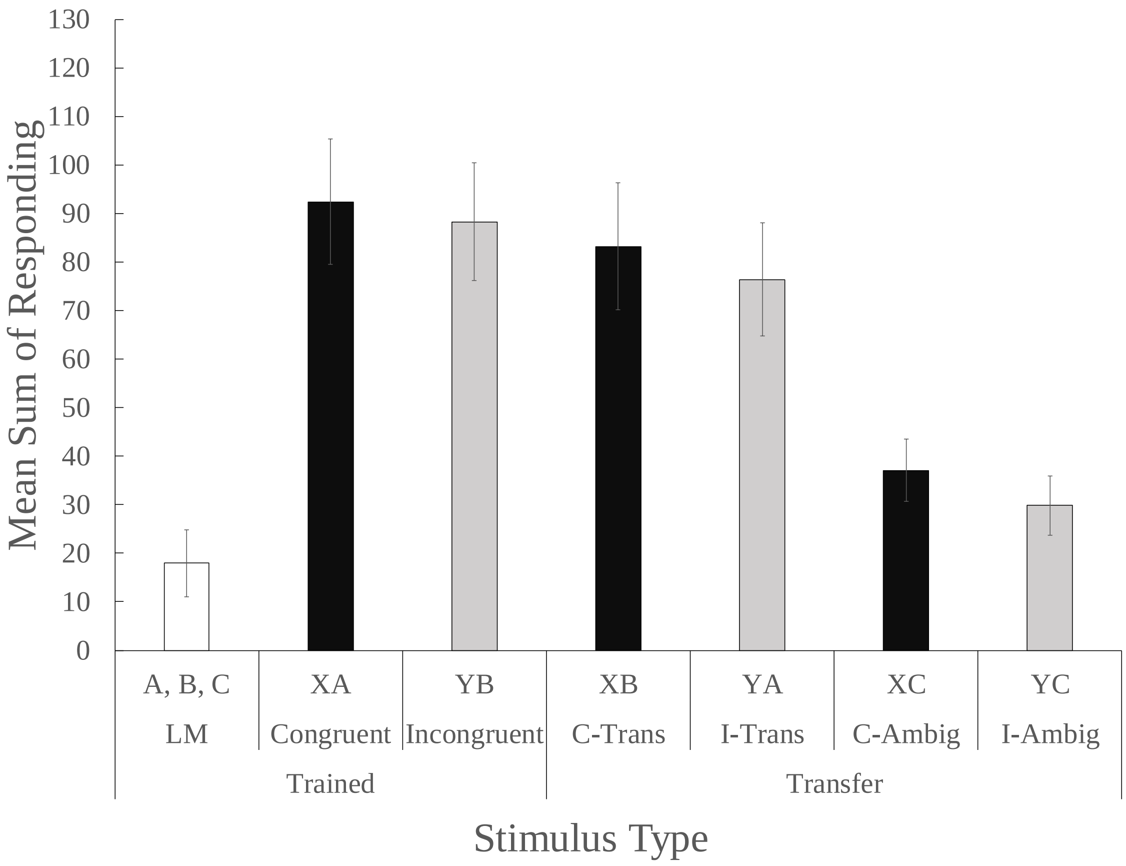


Figure 28. Magnitude of responding during test. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled “Trained”. Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled “Transfer”. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., “I” corresponds with Incongruent). “Trans” indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. Responding on LM alone trials was collapsed across trial types (A-, B-, & C-). Error bars represent standard errors of the means**.**

Accuracy and Difference Score

Training.

A one-way repeated measures ANOVA was conducted to compare the effect of compatibility type (Ambiguous, Congruent, & Incongruent) on response accuracy for the first response to one of the eight response locations after the OS had been touched during the last two blocks of training. The results did not demonstrate a significant effect of compatibility type, $F(2, 66) = 1.75$, $p > .05$. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was not different than chance for Congruent or Incongruent trials, $ts(33) < .79$, $p > .05$, but was less than chance for Ambiguous, $t(33) < -2.09$, $p < .05$. Figure 29 displays the mean response accuracies for each compatibility type during the last two block of training.

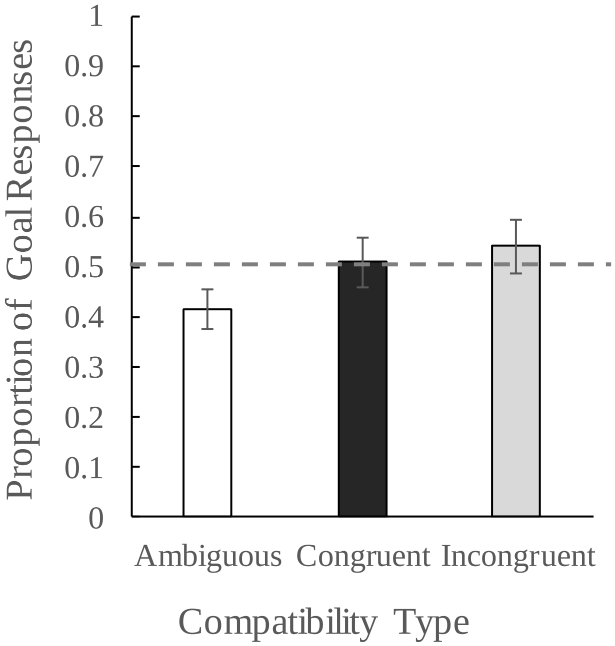


Figure 29. Mean proportion of responses occurring at the correct goal location for each compatibility type during the last two blocks of training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means.

Testing.

First response.

A paired-samples *t*-test conducted on the mean of the first response to one of the eight response locations after the OS had been touched to determine if participants responded more accurately during one of the training compatibility types (i.e., Congruent & Incongruent) revealed no significant difference in accuracy for Incongruent (*M* = .66, *SD* = .21) or Congruent (*M* = .69, *SD* = .21) trials at test, *t*(35) = .78, *p* > .05. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Congruent and Incongruent trials, *ts*(35) > 4.60, *ps* < .001.

As previously stated a difference score was calculated for transfer trials at test to get a measure of spatial control. The difference score for each transfer trial type (XB, YA, XC, YC) was compared to a constant, zero, with a single-sample *t*-test. Only transfer trial YC (*M* = .42 *SD* = 1.08) was significantly different than zero, *t*(35) = 2.32, *p* < .05. Figure 30 displays the mean first response accuracies for each compatibility type and the difference score for transfer trials during test.

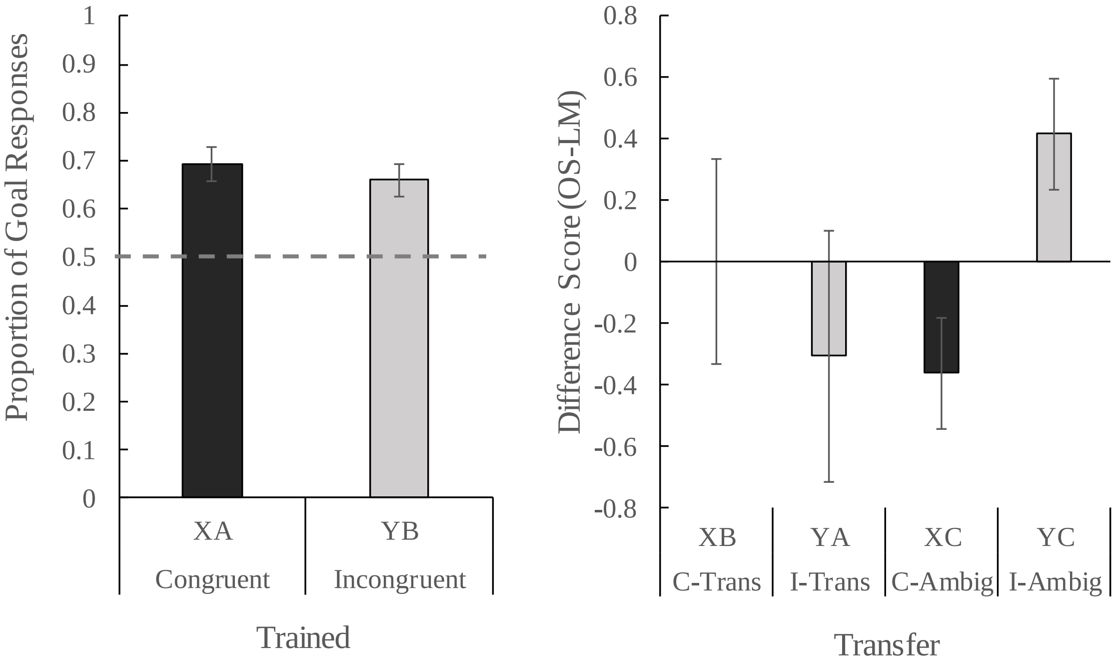


Figure 30. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for first response only. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled “Trained”. Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled “Transfer”. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., “I” corresponds with Incongruent). “Trans” indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means.

All responses.

A paired-samples *t*-test was conducted on the mean of all responses to one of the eight response locations after the OS had been touched to determine if participants responded more accurately during one of the training compatibility types (i.e., Congruent & Incongruent) than the other at test. Participants were not significantly more accurate on Incongruent trials (*M* = .63, *SD* = .24) compared Congruent (*M* = .62, *SD* = .24) at test, *t*(35) = -.12, *p* > 05. Response accuracy for each compatibility type was compared to chance, .5, with a single-sample *t*-test. Response accuracy was above chance for Congruent and Incongruent trials, *ts*(35) > 3.08, *ps* < .001.

As previously stated a difference score was calculated for transfer trials at test to get a measure of spatial control. Any positive difference score indicate OS controlled responding at test while any negative difference score indicates that the LM controlled responding. The difference score for each transfer trial type (XB, YA, XC, YC) was compared to a constant, zero, with a single-sample *t*-test. Only transfer trial YC (*M* = 9.33, *SD* = 25.41) was significantly different than zero at test, *t*(35) = 2.20, *p* < .05,. Figure 31 displays the mean response accuracies for each compatibility type and the difference score for transfer trials during test for all responses.

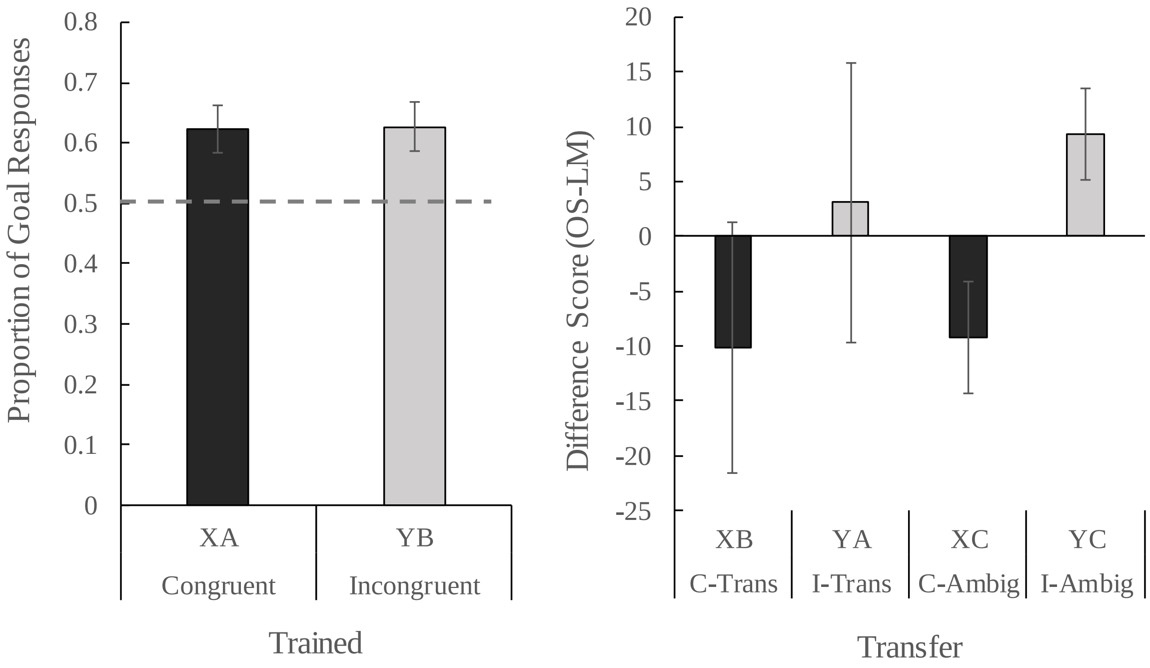


Figure 31. The left panel displays response accuracy as the mean proportion of responses occurring at the goal location (non-reinforced) and the right panel displays the mean difference score during test for all responses during test. Testing trial types that consisted of stimuli from training are on the left side of the figure and labeled “Trained”. Novel testing trial types that consisted of new combinations of stimuli are on the right side of the figure and are labeled “Transfer”. The letters “C” and “I” represent the OS from training used in each transfer trial and correspond to the training compatibility type (e.g., “I” corresponds with Incongruent). “Trans” indicates a transfer trial where the OS-LM pair utilized the LM from Incongruent and the OS from Congruent, or vice versa. “Ambig” indicates a transfer trial where one of the training OSs was paired with LM C, which provided ambiguous information about the location of the hidden goal during training. The dotted gray line represents chance level of responding. Error bars represent standard errors of the means**.**

Response Latency

All statistical analyses for response latency were conducted on the log transformed data (Lg10) and raw data were used for the figures and descriptive statistics.

Training.

A one-way repeated measures ANOVA with a Greenhouse-Geisser correction was conducted to compare the effect of compatibility type (Ambiguous, Congruent, & Incongruent) on the response latency during the last two blocks of training. There was no significant effect of compatibility type, $F(1.83, 60.53) = .255$, $p > .05$. Figure 32 displays the raw data mean response latencies for the different compatibility types during training.

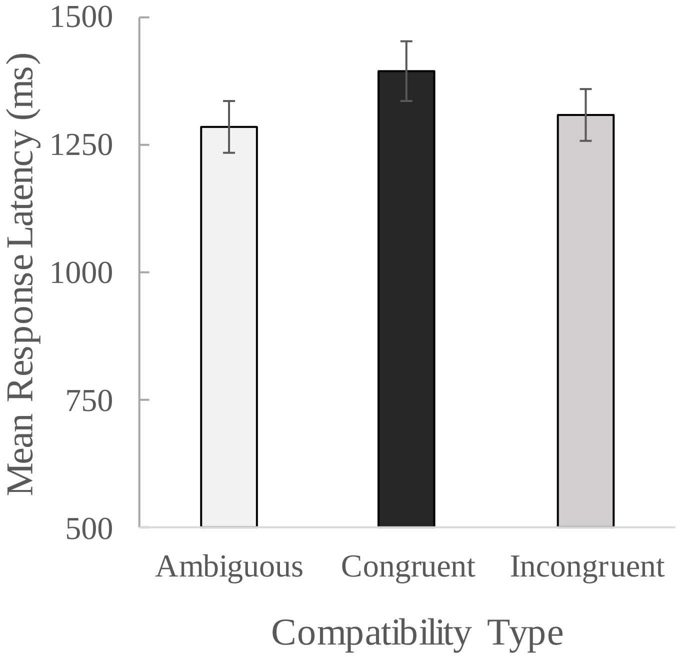


Figure 32. Response latency in ms for each of the compatibility types during the last two blocks of training. Error bars represent standard errors of the means**.**

Testing.

A one-way repeated measures ANOVA with a Greenhouse-Geisser correction was conducted to compare the effect of stimulus set (Congruent, Incongruent, C-Trans, I-Trans, C-Ambig, & I-Ambig) on the latency to respond. There was no significant effect of stimulus set at test, $F(3.08, 73.95) = .85$, $p > .05$. Response latency differences were expected at test, especially for the originally trained trial types (i.e., Congruent & Incongruent). A paired samples *t*-test was conducted on the mean response latencies for Congruent and Incongruent trials at test revealed no differences in response latency at test for Congruent trials ($M = 1394.10$, $SD = 52.75$) or Incongruent ($M = 1524.33$, $SD = 56.29$) at test $t(34) = -1.59$, $p > .05$. Response data were collapsed for compatible OSs (i.e., XA, XB, & XC) and incompatible OSs (i.e., YB YA, & YC) at test. A paired-samples *t*-test revealed that participants responded significantly faster on compatible ($M = 1402.2$, $SD = 287.73$) than incompatible ($M = 1509.32$ $SD = 355.22$) trials during test, $t(35) = -2.69$, $p < .05$. Figure 33 displays the raw data mean response latencies for the different compatibility types at test.

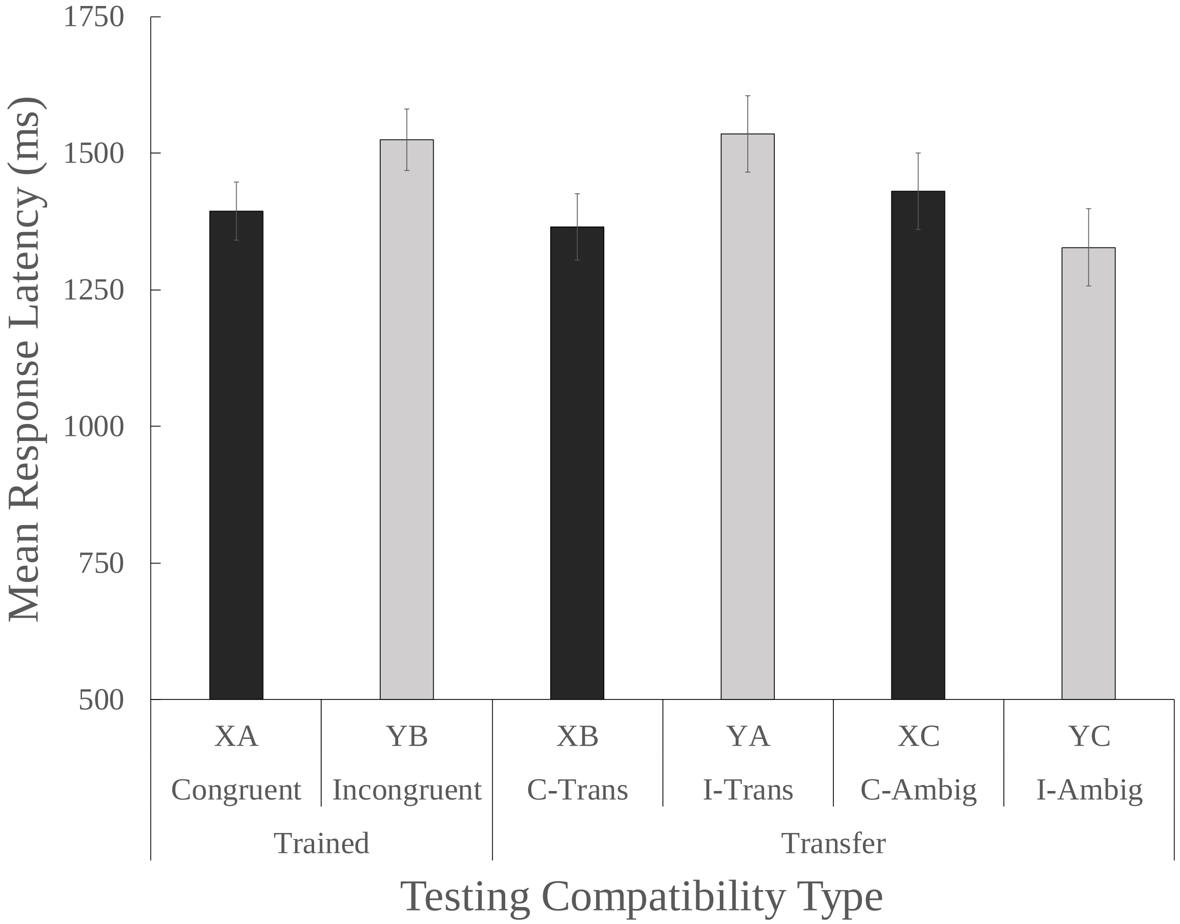


Figure 33. Mean response latency in ms for each of the compatibility types during testing. Error bars represent standard errors of the means**.**

Discussion

Like Experiment 1b and 2, LM and OS stimuli in Experiment 3 were only stable spatial predictors of the goal location when the OS preceded the presentation of the LM during and occasion setting trial. The compatibility types, stimuli, temporal overlap between the OS and LM, and the responses required for each of the compatibility types were identical to Experiment 2. However, in Experiment 3 the OS stimuli were always presented at either the far left or far right response locations across trials instead of appearing near the goal at different locations within the response array. The purpose of this manipulation was to further discourage configural learning and reduce the likelihood of the OSs being treated like LMs. The different compatibility effects produced a significant response latency advantage for Congruent trial types but had no effect on accuracy, participants' ability to learn the occasion setting discrimination, or the ability of the OSs to gain conditional control of responding.

As in the previous two experiments, compatibility type did not affect the acquisition rate of the discrimination. There were also no differences in DR at the end of training for any of the compatibility types, or during testing for the Congruent and Incongruent compatibility types. Discrimination ratios at the end of training and during the non-reinforced test trials, indicated that participants had learned the occasion setting discrimination. The DR also revealed that limiting the overlap and moving the OS stimuli to the edge of the visual display did not prevent acquisition of the occasion setting task.

As in Experiments 1b and 2, the mean magnitude of responding was used to evaluate any differences between stimuli at test. Participants responded less on direct transfer trials (e.g., XB, YA) than test trials with the original OS pairs, but responded the least when OS X or Y was paired with the LM C. The results are consistent with previous occasion setting tasks and replicate the finding from Experiments 1b and 2 (Ruprecht et al., 2014; Leising et al., 2015; Cleland et al., 2017). Previous research demonstrates that due to similar training histories, some level of acquired equivalence between A and B should have resulted in more transfer on XB and YA trials than on XC or YC trials (Bonardi & Hall, 1994). Compatibility level did not influence how much control the OS had over participant responding during the novel transfer tests.

Compatibility level also offered no advantage for response accuracy during training. This result is different than those obtained from Experiments 1b and 2. Accuracy at the end of training was not above chance for either of the compatibility types and accuracy for Ambiguous trials was less than chance. This is likely the reason that neither compatibility type provided a response accuracy advantage. Moving the OS away from the LMs and goal location appeared to have a marked influence on participants' ability to locate the goal during training regardless of the compatibility type. During test there was also no accuracy advantage for either of the compatibility types but the accuracy for both compatibility types was above chance. The improved accuracy at test may suggest that participants were still learning where to respond at the end of training. This is likely due to the increased difficulty, because of the distal placement of the OS with respect to the LM and the hidden goal. It is also worth noting that for the first time, across the three experiments, that there was a small accuracy advantage for Congruent trials (for the first response). This is consistent with the SRC effects that would be expected, even if only descriptive. However, the descriptive accuracy advantage is flipped when looking at all the responses, but any accuracy advantage after the first response is likely due to something other than SRC effects.

The spatial difference scores provided mixed results about how SRC effects influence what is learned about OS stimuli. Despite no accuracy advantage for the trained trials during training or testing, OS Y displayed spatial control for the first and all responses on Ambiguous transfer trials (YC). Contrary to Experiment 1b and 2, OS X was not able to demonstrate spatial control on any transfer trial. Occasion setter X and Y should have been equally reliable and stable in predicting the goal location but OS Y was a slightly more proximal cue than OS X and may explain why OS Y was able control YC responding for the first and all responses. LM A and B were more proximal and stable than either OS, but slightly less reliable than either OS. During transfer tests the LMs provided spatial information that conflicted with the spatial information provided by the OS. Uncertainty should increase participant's reliance on what they learned about the stimuli during training (Cheng et al., 2007). If what participants learned during training about each of the OSs and LMs conflicted when the stimuli were placed in novel transfer trials this may explain why neither the LMs nor OSs were able to control responding on direct transfer trials (XB, YA) during test.

Despite the potential designed SRC effects influencing what is learned about the stimuli, different proximities of the OS and LM stimuli may be a simpler explanation for the spatial control observed during test. It is likely that the 1-s overlap between the OS and LM and presenting the OS stimuli on the edges of the screen prevented the OS stimuli from being treated like LM stimuli because of their decreased proximity to and reliability about the goal location. This allowed for a clearer observation of how the designed SRC effect influenced what was learned about the OS. During Experiments 1b and 2 there was a clear accuracy advantage for Incongruent trial types compared to Congruent trials, going against the original hypothesis, but the finding was complicated by the observation that the participants seemed to treat the OS stimuli as LMs. If subjects are ignoring LM B when OS Y is present and using OS Y as a LM to find the goal directly, then we wouldn’t expect Congruent trials to have an advantage. The results from Experiment 1b and 2 may have also been due to density of stimulation SRC effects (e.g., responding away from X and A on XA trials and toward Y) occurring during each trial that cancelled out SRC based on the location of the goal and landmark relative to fixation. However, after evaluating accuracy data for Experiment 3 this explanation seems unlikely. Moving the OSs to the edge of the response array decreased the proximity between the OS and the goal location but did not change the fact that the stimulus-response set on Incongruent trials may have actually been more congruent. However, it should have eliminated the density of stimulation SRC effect that may have explained the increased accuracy on Incongruent trials during

Experiments 1b and 2. Despite this potential additional SRC effect (for Congruent & Incongruent compatibility types) during Experiment 3 the Incongruent trials did not provide an accuracy advantage. In fact, this was the first indication that Congruent trials may provide an accuracy advantage as originally hypothesized.

The different compatibility types did not provide any response time advantage during training or testing. However, when the data were collapsed across compatible (X) and incompatible (Y) OS stimuli, participants displayed shorter response latencies on test trials when OS X was part of the stimulus pair. As with the accuracy data, this was the first evidence of congruent OS stimuli providing an advantage across any of the experiments. This result also indicates that it is unlikely that the physical distance between the OS response and the response to the goal location are responsible for the Incongruent response latency advantage in Experiment 1b. Despite the extra distance between the OS response and the required response on Congruent trials (see Figure 26) X provided a response latency advantage at test. The Congruent accuracy advantage during Experiment 3 lends support to the second explanation provided for the Incongruent accuracy advantage during Experiment 1b. It was possible that the position of OS Y directly below the goal location during Experiment 1b and 2 created a situation where participants would have responded faster just because they could potentially find the goal without waiting for the LM. This was not possible in Experiment 3 because the OS was never under the goal location for any compatibility type. Moving the OS away from the goal location took away the OS Y response time advantage and allowed the OS X advantage, due to the compatibility between the stimulus set and the required response, to be observed for the first time. The alternative explanation for competing SRC effects is also not supported by the Congruent response latency advantage observed in Experiment 3. If Incongruent trials were actually more compatible than Congruent trials, then the response latency advantage for Incongruent trials from Experiment 1b should have been observed in Experiments 2 and 3 as well unless OS was acting as a beacon.

In conclusion, Experiment 3 demonstrated that participants were able to learn an occasion setting discrimination when the correct location was dependent on the spatial position of the OS and LM stimuli, when the OS and LM were only together on the screen for 1 s during each trial, and when the OS stimuli were presented on the edges of the response array. As in the previous two experiments, compatibility effects did not affect the speed of acquisition or final DR at training or during testing. Participants also displayed responding during transfer trials consistent with previous occasion setting literature (e.g., Bonardi & Hall, 1994; Ruprecht et al., 2014; Leising et al., 2015), but there was no difference in the magnitude of responding based on compatibility type during training or testing. Consistent with Experiment 2, there were no accuracy differences between Congruent and Incongruent trials during training but there was the first indication of an accuracy advantage for Congruent trials (although small and not statistically significant). However, the spatial difference scores indicated that during novel transfer test trials only OS Y was able to control where responding occurred (YC). Perhaps the most important finding is the response latency advantage for the Congruent OS when data were collapsed across OS compatibility types during Experiment 3. Not only did this result show a compatibility effect that provided an advantage for Congruent trials, it also validated the effectiveness of the SRC manipulation in the current set of experiments. The close proximity of OS Y to the goal location resulted in participants treating it like a LM in Experiments 1b and 2, which resulted in a true SRC effect. That is, in Experiment 1b and 2, participants showed an advantage when responding to the stimulus signaling the hidden goal (i.e., OS Y as a beacon) instead of at a location away from the source (OS X). It may be that the only way to observe directional SRC effects is to remove the density of stimulation SRC effect or prevent OS Y from being treated as a beacon for the hidden goal.

The manipulation in Experiment 3 was successful in preventing the OS stimuli from being treated as LM and therefore was able to provide evidence in support of the original hypothesis. Under these conditions, congruent arrangements produced performance advantages (response time, accuracy). However, contrary to the hypotheses, SRC effects did not influence performance measures associated with occasion setting tasks (DR, spatial accuracy). Experiment 3 could be used to further study the predicted effects of SRC in future research and how these effects influence what is learned about the stimuli in occasion setting tasks, and more importantly, how SRC influences performance measures associated with occasion setting.

General Discussion

The purpose of the current set of experiments was to utilize a spatial occasion setting procedure to determine how SRC effects, if present, influenced the 1) rate of the acquisition 2) response accuracy, 3) latency to respond, and 4) transfer of spatial occasion setting. Previous SRC research has predominantly utilized a left or right response in the presence of one discriminative stimulus, and most often reported only response accuracy and latency. Previous occasion setting research has utilized multiple stimuli, but has not investigated whether one or another spatial arrangement of the stimuli might facilitate acquisition of and transfer of occasion setting. The current experiments extend previous research by including two stimuli within a compatible or incompatible arrangement to the response, where one stimulus sets the occasion for responding to the second. In addition, rate of acquisition and transfer were included in the analysis. Results from the current experiments demonstrate that the level of compatibility had little effect on the rate of acquisition or ability of an OS to modulate responding and transfer conditional control in the presence of the discriminative stimulus during a spatial occasion setting task but did influence accuracy and response latencies.

Unfortunately, a thorough discussion comparing pigeon and human performance on the task is not possible due to the low number of pigeons that made it to testing. However, there are some similarities between the species that can be discussed with caution. While the present data cannot definitively identify the mechanism supporting behavior in the task, the similarities in the patterns of data suggests that humans and pigeons solved the task in a similar way. Both species transferred control over magnitude of responding, but differed on the extent that OSs modulated responding on the transfer trials. Both species also showed some response latency and accuracy advantage on Incongruent trial types, although the difference was more pronounced for pigeons. There were also some notable differences in procedure, including contextual variables (e.g., motivation) which may have led to performance differences. Pigeons showed a more pronounced congruency effect. This is likely due to the difference in the nature of the required response for humans (touch) and pigeons (peck). Without an additional experiment we cannot say that it takes longer for pigeons to transition between the OS peck and the hidden goal peck but a pigeon moving its entire head to make a response is very different that a human moving a finger to make a response while keeping head position consistent. Likewise, the distance between OS response and hidden goal response relative the body size of the organism making the response is drastically different between the species. There was also a large difference in the number of sessions during training. Pigeons took an average of 7 (*SD* = 2) sessions to learn the basic occasion setting task and were advanced to testing based on individual performance. Meeting the spatial accuracy criteria took pigeons, an average of 208.5 (*SD* = 2.12) sessions before being advanced to testing. Humans were required to learn the task in one session and automatically advanced to testing in the same session. It is also worth noting that across the three experiments 61 of the 163 participants did not demonstrate accuracy above chance levels during testing. Humans were also responding for treasure whereas the pigeons were responding for grain. Although a thorough comparative analysis is beyond the scope of the current data, similarities in the effects of SRC on accuracy and latency across species, as well as limited transfer for both species informs our understanding of the conditions (e.g., OS-LM spatiotemporal overlap, OS proximity to the goal) that determine SRC effects and OS transfer.

With respect to acquisition of the occasion setting task, all of the experiments demonstrated that whether an occasion setting stimulus was part of a Congruent, Incongruent, or Ambiguous stimulus set there was no difference in how fast or how well the discrimination was acquired during training. These results indicate that the original hypothesis regarding compatibility affecting rate of acquisition can be rejected. The original hypothesis stemmed from the idea that if more errors or incorrect responses are made during one of the compatibility types, then it may take longer to learn that discrimination. This would be especially true if only one response were allowed per trial because an incorrect response would result in a missed opportunity to collect reinforcement and would not help to establish the disambiguating role of the OS stimulus. In the current set of experiments responding was only limited by the duration of the trial and many responses could be made until the hidden goal was found. Therefore, while incompatibility between the spatial position of a stimulus and the required response is expected to cause response time and accuracy deficits, the current results support the idea that in our task the ability to learn the basic occasions setting task was not disrupted. A future experiment could use the design of Experiment 3, but terminate the trial after the first response was made.

Other traditional occasion setting measures were also largely unaffected by the designed SRC effects. For example, compatibility did not influence the amount of conditional control OSs X and Y demonstrated over whether or not responses occurred during transfer test trials. There were no compatibility-based differences during the transfer test, but the overall pattern of responding was consistent with the idea that similar training history and generalization between the stimuli predicts the level of transfer during novel trials (Cleland et al., 2017).

However, it is also clear that these effects alone are not specific to occasion setting, nor were there any reasons to believe they would be. Training any two stimuli (OSs or otherwise) with a similar reinforcing response or outcome will result in an acquired equivalence effect, thereby increasing generalization between them. It is possible that summing the excitatory values of two stimuli from training would produce similar results (e.g., more responding on direct transfer than ambiguous transfer). However, summation does not explain the lack of difference between XB and YA transfer trial or XC and YC transfer trials. If X was a weaker excitatory stimulus then it should have produced less responding when paired with novel stimuli, compared to Y. Thus, even in Experiment 1b, when there was overwhelming evidence that OS Y was being treated as a LM, the same pattern emerged. However, compatibility still didn't result in OS Y or X displaying clear control over where subjects responded on novel test trials.

The designed level of compatibility affected the ability of the different OS stimuli to control where responses occurred during the transfer test trials but which OS demonstrated control was not consistent across experiments. However, this was likely due to a factor other than SRC. Across all experiments OS X and Y demonstrated some conditional spatial control. However, OS Y seemed to demonstrate the most consistent spatial control across the set of experiments indicating that OS Y, and therefore Incongruent trials produced a spatial control advantage. However, as discussed in the specific discussion sections for Experiments 1b and 2 it is likely that OS X and OS Y were not treated the same during training. Specifically, OS X may have been serving a dual role as a more traditional OS, modulating whether or not a response in the presence of a LM will be reinforced, and another role as a LM, whereas, OS Y was acting more like a proximal, stable, and reliable LM, at least in terms of directing responding and gaining conditional control of responding during transfer test trials. This is especially evident when looking at all responses during test for Experiment 2 where only OS X displayed control over responding, despite being the weaker predictive stimulus. The fact that OS Y was very likely acting as LM Y (with merely incidental learning about LM B), reverses the expected spatial control advantage for the congruent versus incongruent OS in the first two experiments. The spatial control and magnitude findings seem to suggest, that at least with this experimental design SRC effects do not alter the strength of OS and therefore do not affect occasion setting specific performance.

It is much more likely that SRC affected performance measures more closely related to typical SRC tasks (i.e., accuracy and response latency). However, the Incongruent accuracy advantage during the pigeon experiment and first two human experiments is likely not due to the predicted SRC. Instead it is much more likely that other stimulus dimensions (e.g., proximity to goal and reliability about where to respond) caused the OSs in the Congruent and Incongruent trials to be treated differently than one another as mentioned above. This idea is further supported when comparing first response accuracy to all response accuracy at during testing. Any SRC effects should have been observable during the first response because after the first response the mechanism driving the compatibility effects, (the automatic coding of the spatial position of the LM stimuli and the generated response code required for a correct response) is no longer active. The accuracy advantage for Incongruent trials was most observable when all responses were analyzed during Experiment 1b where the first response could be corrected and OS Y could be used on its own to locate the hidden goal. An accuracy advantage caused by SRC effects should show up only for the first response. This means that any conclusions about the designed SRC effects from the first two experiments are likely misplaced because it is much more likely that Y was treated as a LM, and that SRC effects, even those not predicted, were overpowered.

Occasion setter Y may have prevented the observation of the intended directional SRC effects because of its salience during training. Occasion setter Y may have acted like a beacon during Experiments 1b and 2. If OS Y was acting as a beacon, the performance advantages during Experiments 1b and 2 for Incongruent trials are expected given that SRC research has shown responding is faster and more accurate if the correct response is in the direction of the source of stimulation (Simon, 1968). The design of Experiments 1b and 2 presented OS Y very close to the hidden goal. The close proximity and reliability of OS Y to the goal location and requiring participants to respond to the OS likely made OS Y more salient than any of the LMs, therefore increasing the likelihood that it would be treated as a LM and overshadow or completely mask directional SRC effects.

The design manipulations of Experiment 3 should have prevented the OSs from being treated like LM stimuli (or a beacon in the case of OS Y) and allowed for a much clearer observation of any accuracy differences caused by directional SRC. The first indication of a Congruent trial SRC effect is seen for the first response at test and it is only when all responses are observed that this insignificant accuracy advantage appears for Incongruent trials. Across all experiments, first response data is the only reliable indicator of compatibility effects and for the first time the hypothesized compatibly effect can be seen.

A small, non-significant accuracy advantage for Congruent trials during test is insufficient evidence on its own to indicate that SRC effects influence occasion setting performance. However, the progression of response latency differences across experiments also indicates that SRC did influence occasion setting performance (see Figure 34). While it is unlikely that any differences, in accuracy or response latency, between the Incongruent and Congruent trials during Experiments 1a, 1b, or 2 are due to the designed directional SRC effects, Incongruent trials provided a clear response latency advantage for pigeons and humans. In addition to OS X and Y stimuli potentially being treated differently in those experiments, the distance required from OS Y to the goal location was much shorter on Incongruent trials than Congruent trials. This is the simplest and most likely explanation for the Incongruent response latency advantage during Experiment 1. However, during Experiment 2 neither the Congruent or Incongruent trials produced faster response latencies. If the Incongruent trials could not produce a response latency advantage during Experiment 2 it is possible that the designed SRC effect required inhibition of automatically responding in the direction of the stimulus presentation to respond accurately and negated any latency advantage otherwise expected for Incongruent trials, given how close OS Y was to the goal. OS Y was directly beneath the goal location making it a more proximal and stable LM stimulus than any other stimulus during occasion setting training and should have provided a response latency advantage. However, no response latency advantage was observed for Experiment 2, possibly due to the designed SRC effect.

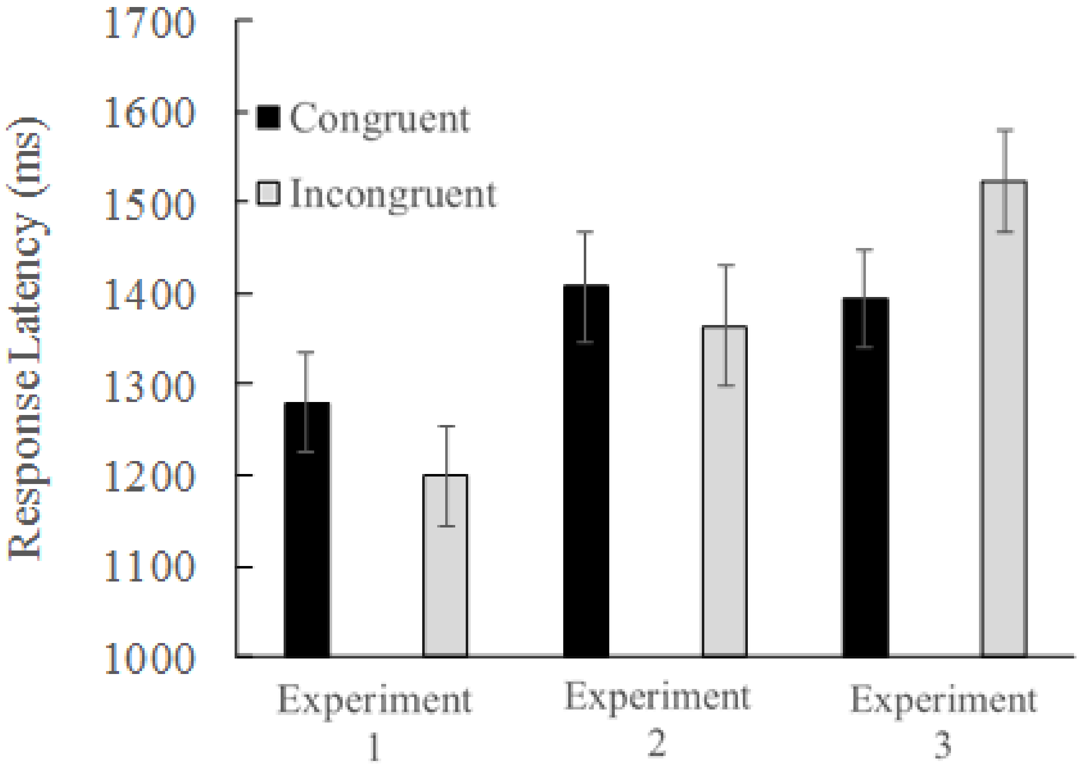


Figure 34. Displays the average response latencies for the trained trial types during testing for each experiment. The error bars represent the standard errors of the means.

Once again the design of Experiment 3 allowed for a clearer look at latency differences caused by SRC effects. Moving the OS away from the goal location should have neutralized most of the effect of OS Y being located directly beneath the goal. However, given the positioning requirements for Congruent and Incongruent trials (see Figure 26) OS Y was still, on average, closer to the goal location and should have provided a response latency advantage for the Incongruent trials. Despite having to move a greater distance to the predicted goal location on trials with OS X (which should take longer), a significant decrease in response time was found during test across all test trials with OS X. This is perhaps the strongest evidence of SRC effects influencing performance on a spatial occasion setting task. It may also be the case that

SRC effects are easily overpowered and require a very specific procedure to be observed in a spatial occasion setting task even when looking at specific performance measures related to the typical SRC task.

Without clear evidence of SRC directly impacting typical occasion setting performance measures, and in the absence of the additional test trials (extinction of the OS or transfer tests with LMs not trained in an OS relationship) that are used to determine the identity of the presumed OS stimulus, alternate explanations for how the task was solved must be considered. Namely, that the current design is no different than a sequential response task, that the stimuli in the task were learned about as a configuration, or that the OS stimuli are simply generalized excitatory stimuli.

At first glance the design of the experiment resembles a sequential response task because a response to the first stimulus generates another stimulus and a response decision is made in the presence of the second, utilizing information signaled from the first stimulus. One major difference between the current occasion setting task and a typical sequential response task is that during a sequential response task the first response to a stimulus is a choice (e.g., pick stimulus A, or B) then the response in the presence of the second stimulus is a binary decision, usually whether the second stimulus is a match or not-match to the first stimulus, or some other arbitrarily decided rule that fits the procedure (Cleaves, 1977). The information from that first response is important but only informs a binary response that aligns with a rule given to participants at the outset of training. In the current set of experiments, a correct response in the presence of the second stimulus is dependent on learning the spatial relationship between the first and second stimuli. It is clear that the current experiment is not a sequential response task but there are additional explanations to consider.

Participants may have learned to solve the task by treating the stimuli like a configuration instead of individual stimulus elements. Had the stimuli been learned about as configuration during training, then at test the novel OS and LM combinations would have been treated as new stimulus configuration with no prior history of reinforcement (in a strict interpretation of configural learning). A more modern interpretation would suggest that generalization would still occur among the elements that make up the configuration (Schmajuk et al., 1988). However, the loss of transfer due to the presence of a new configuration would likely have led to a lower response magnitude during transfer trials. Both OSs transferred modulatory control over whether or not responding occurred during the transfer test to the other LMs from training and the pattern of responding across all of the experiments are very similar to the transfer that is expected based on the similar training histories of the stimuli (Cleland et al., 2017). Generalization decrement between the trained and transfer stimuli may explain the fact that there was less responding on transfer trials than trained trials at test but cannot explain the difference in magnitude of responding between the direct transfer trials and the ambiguous transfer trials. All the OSs and LMs had similar size, shape and general proximity to the goal location during training and generalization decrement would predict that there should be no difference in responding on direct transfer trials and ambiguous transfer trials, yet across all of the human experiments there is less responding on ambiguous transfer trials (OS+ LM C). This pattern of responding is exactly what you would expect if X and Y were acting as OS during the transfer tests. Although some configural learning may have occurred, and help to explain the individual weighting of each stimulus in a configuration by its salience and may explain some of the spatial control results (e.g, the cancelled out spatial control when two very salient and reliable stimuli, OS Y and LM A, on transfer trial YA were combined) there is not enough evidence to conclude that the stimuli were only learned about as configurations during training. The designs of the experiments also explicitly discouraged configural learning, especially in Experiments 2 and 3 when the OS and LM overlap time was limited to 1 s and the OSs were moved away from the LMs.

While the evidence from the three human experiments (e.g., magnitude difference between direct and ambiguous transfer trials) suggests that the task was solved by an occasion setting mechanism as designed, it does not rule out the more compelling argument that a failure to create a task that created differing levels of compatibility is the reason that SRC effects failed to differentially influence performance on traditional occasion setting measures. Whereas it is difficult to use the data from the first two experiments to make any concrete decisions about the presence or absence of SRC effects, Experiment 3 clearly demonstrates that participants responded faster and more accurately (at least descriptively) on trials consisting of OS X. However, even in this experiment SRC only affected performance measures typically associated with SRC tasks (accuracy, latency to respond) and not those associated with occasion setting (DR, transfer of control).

The ability of participants and subjects to learn an occasion setting discrimination during a procedure that also created differing levels of compatibility indicates that the current experimental design is a novel and potentially useful tool for investigating how SRC effects influence what is learned about stimuli in conditional discriminations and how SRC effects develop in a procedure as participants learn the correct stimulus-response set instead of being informed of the rules for a given stimulus-response set at the outset of training.

Stimulus response compatibility did influence performance in the current occasion setting experiments but only performance on measures typically associated with SRC tasks. The effects were either masked by other relevant stimulus factors, such as proximity or the reliability of LM stimuli (Experiment 1), cancelled one another out (Experiment 2), or were simply not strong enough to influence acquisition rate or the ability of OSs to gain conditional control over responding (Experiment 3). Experiment 3 revealed how SRC effects can influence performance within the current spatial occasion setting design, but it is clear that more research needs to be done to determine at what point these SRC effects will influence performance during an occasion setting task beyond typical measures of SRC, and at what point these effects become detrimental to productivity or safety when deciding whether or not and where to respond in a novel situation.

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Appendix A

Experiment: _____________
Participant Number: ______

Select List: ______________

Color scheme: ___________

Debriefing:

What kind of information did you use to approximate to the goal (e.g., did you use colored squares, or the patterned squares in the response array?

Did you notice that the colored squares were switched for some trials? Especially the recent trials you completed when no feedback is given?

If so, how confident were you in your responses?

If I tested you again with new colors and patterns, would you rely colors or patterns more to guide your response?

READ TO PARTICIPANT

Finding things in space, like our lost keys for example, can be difficult. We believe higher-order processes might be at work, requiring us to integrate spatial information across time. In this task, you observed a series of colors and objects. On many trials, the first colored feature set the occasion for whether or not the second object was paired with rewards, and may have also told you where (left vs right) you had to search to earn rewards. The characteristics of spatial memory are still being debated, and the purpose of this research is to gather more information on the nature of memory by testing your ability to integrate information over time (e.g., few or many items, short or long display, simple or complex items). Thank you for your participation. Please do not discuss the specifics of this experiment with your friends. We want all of our participants to start the task with no previous knowledge. If you have any questions, or would like additional information please contact Professor Joshua Wolf in the Department of Psychology. He can be reached by email: Wolfj@arcadia.edu.

VITA

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ABSTRACT

THE EFFECTS OF STIMULUS-RESPONSE COMPATIBILITY ON RATE OF LEARNING AND TRANSFER OF STIMULUS CONTROL DURING SPATIAL OCCASION SETTING

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Whether or not an organism survives on a daily basis is heavily dependent on the ability of that organism to make quick and accurate responses in the presence of different environmental stimuli to best meet its needs. This is especially true when an organism encounters new stimuli or novel combinations of stimuli and must decide how to respond based on previous learning. The current set of experiments examined how Stimulus-Response Compatibility (SRC) influences what humans and pigeons learn about stimuli during a Spatial Occasion Setting task presented on a two-dimensional touchscreen monitor. The results for the current set of experiments indicated that differing levels of compatibility between the required response and the spatial positioning of stimuli only influenced performance on measures typically associated with SRC tasks (response time and accuracy) but did not influence occasion setting performance measures (acquisition rate, transfer of conditional control). Additional research is needed to determine if SRC effects can influence occasion setting performance and at what point these effects become dangerous or detrimental to productivity.