

MANIPULATIONS OF THE SPATIAL STABILITY OF AN OCCASION SETTER ALTER
SOME ASPECT OF BEHAVIOR DURING A LANDMARK-BASED SEARCH TASK

By

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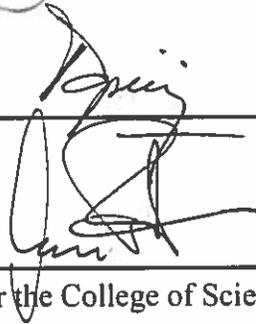
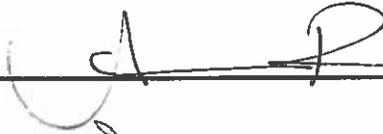
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Lauren Cleland

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Manipulations of the Spatial Stability of an occasion Setter Alter Some Aspects of Behavior During a Landmark-based Search Task

Various cues (e.g., visual features) in an environment can signal to an animal if reinforcement is available. Learning the conditions under which a response (e.g., foraging) will be reinforced (e.g., finding food), will likely increase an animal's odds of survival and procreation. Discriminative stimuli (DSs) and occasion setters (OSs) are conditional cues that signal the probability that a response will be reinforced. DSs are cues that responding comes under the control of. OSs differ from DSs in that OS signals when a response will be reinforced in the presence of a DS.

OSs are conditional cues that have wide ranging effects in a multitude of situations. In social situations, animals use OSs to respond appropriately to animals within and outside their own group (e.g., responding to a friendly or an aggressive conspecific). For example, McComb, Packer, and Pusey (1994) found that simply knowing whether a defending group of lions detected an intruder's roar did not predict the group's response. Female lions in groups treat a roar detected as an intruder's roar differently depending on the size and composition of their own group. Humans use OSs to help determine meaning in language (Catania, 1998). In one situation (e.g., a card game) the words "hit me" may mean something very different than in another situation (e.g., an altercation with an aggressive person).

The importance of conditional cues has further been noted in clinical settings with clients suffering from phobias or addiction (Bouton, 1994; Conklin & Tiffany, 2002). During the treatment of anxiety, depression, or phobias, counter conditioning or extinction of the stimulus associated with the unwanted behavior and emotions does not always generalize to situations outside of the clinical setting. The cues in the clinical setting form an important part of the new

associations that the clinician helps the client form. This results in responses that are only expressed in the presence of the cues provided by the clinical setting. This is troubling as any treatment needs to generalize beyond a clinical setting for it to be effective. Despite what has been already learned about OSs, there is still an ongoing debate regarding their function, the conditions under which they develop, and the conditions under which they transfer to new stimuli (Cleland, Ruprecht, Lee, & Leising, 2017; Leising, Hall, Wolf, & Ruprecht, 2015; Bonardi, Robinson & Jennings, 2016).

Prior Research on Occasion Setting

Pavlovian and operant serial feature-positive discriminations are examples of procedures that are used to examine how animals use multiple cues, both in unison and separately, influence responding. In these procedures, the OS (also called a feature) signals the relationship between a stimulus (a) and a biologically significant outcome (e.g., food). In a Pavlovian, serial feature-positive task a conditioned stimulus (CS) comes under the control of an OS that precedes it in time. The conditioned stimulus (CS a) only predicts the biologically significant unconditioned stimulus (US) when it is paired with the OS (OS X). In an operant, serial feature-positive discrimination, a response in the presence of a discriminative stimulus or target (DS a) is followed by a biologically significant outcome (e.g., food) only when it is preceded by an OS (OS X). Much of the language used to describe operant and Pavlovian feature-positive procedures are interchangeable.

Both Pavlovian and instrumental serial feature-positive procedures involve trials of X followed by a in which the US or reinforcer is delivered ($Xa+$) as well as trials of a alone in which reinforcement is not delivered ($a-$). When trained with this procedure animals respond to a when it is preceded by X , but not to a when it is presented alone (see Swartzentruber, 1996, for a

review). The target can be presented simultaneously with the OS, but this arrangement does not typically result in occasion setting. Instead, the resulting behavior indicates learning of a direct relationship between X and the reinforced response. In fact, there are several procedural manipulations which can alter the kind of learning that results from a feature-positive procedure (Miller & Oberling, 1998). The kind of learning supporting accurate performance in a feature-positive discrimination can be investigated by measuring the topography of the response produced on Xa trials, the effect of extinction of the OS on Xa trials, and measuring transfer during transfer trials in which the OS is paired with a different target from training (e.g., Xb).

The Topography of the Response

In a standard feature-positive discrimination, X and a are simultaneously presented and reinforced on some trials and a alone is presented and nonreinforced on other trials. With this procedure, only X acquires consistent control of behavior (Hearst, 1979). In other words, the animal learns about the direct relationship between X and the reinforcer (X -reinforcer). This results in OS X becoming an excitatory conditioned or discriminative stimulus. In these instances, behavior can be explained by Pavlovian or instrumental conditioning, respectively. However, when the target and OS are presented serially, the resulting behavior suggests another kind of learning may result, in which responding occurs to the common element (a) of the combination Xa but is released by the feature (X). This latter learning is what is referred to as occasion setting, or hierarchical learning. Some evidence that differentiates between learning about the X -US relationship and occasion setting comes from Pavlovian, feature-positive discriminations in which the different response forms elicited by stimuli associated with food are used to help determine what is learned during occasion setting.

The form of a conditioned response is influenced by the nature of the CS (Holland, 1977). An auditory CS evokes startle, head jerk, and magazine behaviors, while a visual CS evokes rearing and magazine behaviors. If a direct X -US connection is responsible for conditioned responding during trials of $Xa+$, then the form of the response should match X . However, if X is releasing a response to a , then the form of the response should match a . In Experiment 1, Ross and Holland (1981) trained rats on a Pavlovian, simultaneous feature-positive procedure in which one group of subjects were trained with trials of a tone (a) followed by the US but only when the tone was presented with a light ($Xa+$), and not when the tone was presented alone ($a-$). Rearing, expected when a visual CS is paired with a food US, accounted for 50% of the observed behavior, whereas, head jerking made up less than 10%. This suggests that responding was mostly controlled by X . In Experiment 2, rats were presented with serial presentations of the light followed 5-s later by a tone and the US ($X \rightarrow a+$), as well as trials of the tone alone ($a-$). On $X \rightarrow a$ test trials, the light elicited rearing (35% of total behavior) and magazine behaviors (5%), and the tone elicited primarily head jerking (30%) with no rearing. Despite the same temporal proximity and contingency of the tone to the US across groups, the rats in Experiment 2 demonstrated more of the modality specific behavior expected in the presence of the tone (a). This indicates that the animals who underwent feature-positive training acquired learning to both the tone and the light, but that only in the serial group did the light release a head jerking response to the tone and no rearing behavior during the tone.

Extinction of the OS

Further support that OSs do not function solely as conditioned excitators comes from experiments in which posttraining extinction of responding to the OS alone does not affect the OS's ability to control responding to a target (Rescorla, 1986). If occasion setting promotes the

formation of an excitatory association between the OS and reinforcement, extinction of the OS should eliminate responding during future feature-positive trials with the extinguished OS.

However, if an OS facilitates responding to a target, then extinction of the OS should have no effect on responding to the target on subsequent OS-target pairings.

Rescorla (1986) trained pigeons to respond to the illumination of a key light, but only when it was preceded by a noise or a light. The pigeons were also presented with nonreinforced trials of the illuminated key light alone. After training, one of the OSs (i.e., the light or the noise) was presented alone with no reinforcement. This should have resulted in extinction of any excitatory association that the OS had formed with reinforcement. After extinction, the extinguished OS was paired with the illuminated key light and responding was measured. Extinction of the OS did not affect its ability to modulate responding to the illuminated key light relative to the OS that had not been extinguished.

A second test examined the effect of increasing the excitatory value of the OS. The OS that had not been extinguished before the first test was now presented alone and reinforced. At test, pigeons responded equally to the illuminated key light when preceded by the OS that had been reinforced relative to an OS that had not been treated. Changing the excitatory value of the OS alone did not affect its ability to modulate responding to a target.

Transfer of Occasion Setting

Transfer tests are another way to help determine what is learned during acquisition of feature-positive discriminations. In a transfer test, an OS is paired with a target that it was not paired with during training. If transfer occurs, the OS is able to transfer its modulatory properties to a new target. There are certain conditions that facilitate transfer. For example, feature-positive discriminations that contain two sets of OS-target pairings (e.g., $Xa+/Yb+$) allow for the

examination of an OS's ability to modulate a new target (e.g., test trials of Xb - and Ya -). Transfer tests show that when a target is paired with a different OS than from training, responding to the target when paired with the transfer OS will remain higher than responding to the target alone (Holland, 1989). However, responding is often not as high during the novel transfer pairing relative the original pairing (Swartzentruber, 1996). It is only under certain conditions that modulation by the OS is fully transferred to a different target.

Holland (1995) trained rats on an operant, serial feature-positive procedure. Group R_1+R_2 was trained with two occasion setting pairs and two different responses, a chain pull and paddle push. One response was reinforced on trials of Xa and the other response was reinforced on trials of Yb . No responses were reinforced on a and b alone trials. Both responses were reinforced on trials with a conditioned DS or excitator (c) that was never paired with an OS during training. Extinction trials of c alone were presented prior to testing. During transfer tests, an OS was paired in a novel configuration with a previously modulated (Xb / Ya) or a previously non-modulated (Xc / Yc) target. The results of Test 1 indicated that responding in the presence of b on the transfer test (Xb) matched that of responding to b during training (replicating the topography of the response effect reported by Ross and Holland, 1981) and was complete relative to original training (Yb). Responding on transfer trials of c paired with an OS was on average higher than trials of c alone, but reliably less than responding during the Xb transfer test. The form of the response on the Xb transfer test matched responding during training with b , providing strong evidence that X and Y did not control the response directly. The presence of complete transfer was evidence that control by the OS was not limited to the target with which it was trained. Explanations for partial and complete transfer will be discussed further in the section on acquired equivalence.

Accounts of Feature-Positive Discrimination

The evidence indicates that learning that occurs during training of a serial, feature-positive procedure differs from what is learned after conditioning of a CS. Occasion setting, which implies a non-associative mechanism for modulating the relationship between target and the outcome is one possible explanation for the behavior that results after feature-positive training. However, a remaining associative explanation predicts feature-positive discrimination and some degree of transfer. Additionally, a nonconfigural associative account of learning to the compound Xa , suggests that stimulus X and a both enter into associations with the US and the resulting conditioned response during Xa is the result of the summation of the excitatory values of stimulus X and a (Rescorla, 1969).

Configural Account

A configural account of learning suggests that any stimulus compound (Xa) cannot be broken down into only its individual elements (stimulus X and a); rather, Xa is a unique stimulus that enters into an association with a US (Pearce, 1987). In a configural account of occasion setting, the OS and the target come to form a perceptually different stimulus than the OS or the target alone. When the target is presented with the OS, the target may come to look perceptually different from that same target when it is presented alone (Pearce & Hall, 1980; Pearce, 1987; 1994). Due to this, the OS and the target become a unique stimulus that has associations independent of the OS or the target alone.

Stimuli that are presented in compound, as well as individually, can acquire associative strength separately. If the separate element a is nonreinforced but the compound Xa is reinforced, as in feature-positive training, the individual element acquires no associative strength, while the element unique to the compound will develop excitatory associative strength. The end result is

that the animal will stop responding to a alone, but will respond to the compound Xa despite the individual elements developing no control over behavior (Rescorla, 1973). Such an account can explain feature-positive discrimination, but fails to explain transfer. During a transfer trial, the nonexcitatory individual elements are combined into novel compounds, which have no history of reinforcement. Consequently, no transfer of responding to the target is expected.

Pearce (1987) expanded on a configural account of learning to explain transfer. He noted the importance of the experimental context in learning, suggesting the stimuli presented during an experiment come to form a configuration, and that the entire experimental context (C) becomes a part of that configuration. During training an animal forms a representation of the entire context, which is active when the Xa stimulus compound is presented with the reinforcer. The entire representation of the experimental context becomes associated with the configuration and reinforcer. If training consisted of Xa and Yb as well as a and b alone, during a transfer trial stimulus Xb will activate the portion of the representation that contains elements of stimulus X , a , and the experimental context C , all of which are excitatory and the end result is responding to the XCb compound. The stimulus compound XCb in the same experimental context as the excitatory Xa will result in generalization of excitation from the XCb compound. The more common elements the transfer stimulus has, the stronger transfer is. This account explains partial transfer, but could not account for any instances of complete transfer.

Wagner (2003, 2008) described another configural account, REM-SOP, which is a combination of the “sometimes opponent process” (SOP) model and “replaced elements” model (REM) to explain performance in a feature-positive discrimination. The model assumes a finite amount of elements that are active under certain conditions. This account states that when the compound Xa is presented, X and a activate both context independent (i.e., X_i and a_i , active any

time the stimulus is present) and context dependent elements (i.e., X_a and A_x , only activated when other contextual constraints are met, like X and a together). When X is presented alone, the context independent elements that make up X and the context-dependent $X_{\sim a}$ (X without a) are active. Stimulus a also activates its own context independent and context-dependent elements. The context-dependent elements of X are sensitive to the presence or absence of a , and the same can be said for a . This model predicts that during serial, feature-positive training the context-independent elements for X and a are weakened and the context-dependent elements X_a and a_x are strengthened.

Vogel, Ponce, and Wagner (2017) used the parameters dictated by REM-SOP to simulate data in a simultaneous and serial feature-positive discrimination. The simulations predicted an account of control by the context-independent X elements (X_i) in a simultaneous procedure and control by the context-dependent elements (X_a and a_x) in a serial procedure. This account is incomplete as it cannot account for transfer effects. If animals were trained with two feature-positive pairs ($Xa+ / Yb+ / a- / b-$), then the presentation of Xb would result in the activation of context-independent X and b elements, and context-dependent elements of $X_{\sim a}$ (X without a), $b_{\sim Y}$, which after feature-positive training would result in no responding to b with X (Vogel, Ponce, & Wagner, 2017). Critically, what is missing on these trials are the context-dependent elements (X_a , a_x , Y_b , b_Y) which supported responding during training. To explain transfer during occasion setting, the model needs to assume that presentations of Xb resemble presentations of Xa and Yb , thus supporting generalization between them.

Vogel, Ponce, and Wagner (2017) proposed a common cue addition to REM-SOP, which asserts that features (e.g., visual and temporal) common to both configurations would be present on trials of Xa and Yb . As a result, trials of X and a together would be represented by X_i , a_i , X_a ,

a_x , X_c , c_x , a_c , and c_a . The most critical of these for the purposes of transfer would be those containing the common cue c that would still be activated on a transfer trial of X and b . These would include b_c and c_b , which according to the model and simulated data was sufficient to predict excitatory transfer. In other words, when Xb is presented the elements representing the individual stimulus X and b , as well as the elements of X and b with the common cue all come into a state of primary activation and result in responding to the Xb compound. In sum, REM-SOP was able to predict successful feature-positive performance, but unable to predict transfer effects without assuming generalization from the training feature-positive pair to the transfer pair.

Hierarchical Account

Early hierarchical accounts of occasion setting predict that an OS facilitates the activation of the US representation by lowering the threshold for US activation, making it easier for the target to activate the US representation. Activation of the US representation is more likely in the presence of the OS than in its absence (Holland, 1983). Subsequent hierarchical accounts describe the OS as acting upon a specific target-US relationship. These hierarchical accounts of occasion setting state that the OS acts on the excitatory relationship between a specific target (CS) and US, or between a specific target (DS) and response-reinforcer relationship (Bonardi, 1989; Bouton, 1990; Holland, 1983). The OS has no direct association with the US and acquisition does not require any configural learning. Like configural accounts, a target-US specific hierarchical account predicts no transfer of occasion setting, whereas a US threshold account predicts transfer to a target paired with the same US as the original occasion setting pair.

Partial responding is most often reported during transfer. The amount of transfer is evaluated relative to the amount of responding observed when the OS is paired with its original

training target (Holland, 1995). Assuming that generalization occurs between the transfer target and the original target, some degree of transfer will occur. Hierarchical explanations of occasion setting can account for partial transfer effects, but not complete transfer. Interestingly, generalization decrement explains partial transfer for a US threshold account by predicting generalization decrement but some transfer due to a shared US. Successful generalization explains transfer for a target-US specific hierarchical account in that the degree of similarity between the targets and their US will result in generalization from one target-US association to the other. Bonardi, Bartle, and Jennings (2009) tested these accounts of occasion setting and found that transfer is near complete when the transfer OS was paired with a target that had been paired with the same reinforcer as the original target. This result is consistent with the OS acting on a specific target-US association, but also supports US threshold account. Bonardi et al. (2009) expanded on hierarchical accounts to explain these results suggesting that in occasion setting a hidden unit forms an association with both the target-US association and the OS resulting in bidirectional links between the OS and hidden unit, as well as the target-US association. This hidden unit allows the OS to act on the target-US while still adhering to associative conditioning processes. The OS facilitates the activation of a specific target-US association through the hidden unit.

The Role of Acquired Equivalence

Bonardi and Hall (1994) suggest that transfer may be the result of an acquired equivalence effect. This effect suggests that stimuli with similar training histories become more perceptually similar (Honey & Hall, 1987). Transfer tests have shown that an OS can modulate responding to a target it was not trained with, but transfer is most complete when the transfer target was previously trained as a target of another OS pairing. Targets that have been trained in

previous OS pairings may be more effective targets for other OSs due to their shared history as targets in an OS pairing. This shared history of training makes the targets more similar, and therefore, animals generalize learning about the modulatory power of the OS to the new target. This generalization between targets results in transfer (Bonardi & Hall, 1994).

The hierarchical and configural models of occasion setting fail to accurately predict transfer without generalization between OSs and targets. Cleland et al. (2017) tested transfer with visual targets that were either previously trained as targets paired with an OS, trained alone as a DS, or a novel stimulus similar to the other DS. In this experiment the DS was a landmark (LM). LMs are targets that provide reliable spatial information regarding the location of reinforcement. Transfer was found to be complete on transfer trials of the OS paired with a LM that had previously been paired with another OS when compared to responding to the original trained pairing. However, responding to the original trained OS pairing did differ from responding on trials of transfer to the non-modulated LM (X_c). The differences in responding resulting from the degree of similarity in the training history of LMs demonstrated how generalization between stimuli due to a similar training history contributes to transfer of occasion setting.

Occasion Setting in Spatial Tasks

OSs can control more than simply whether or not an animal makes a response or expects a US. Collet and Kelber (1988) found that contextual stimuli (trees, buildings, etc.) can serve as OSs. These contexts can alter where an organism responds in the presence of a LM. Collet and Kelber (1988) found that bees were able to search at different locations within identical huts in relation to contextual cues (i.e., where the huts were located) and LMs in the huts that signaled the positions of sugar water. Inside the two identical huts were two yellow and two blue

cylinders that served as LMs. The arrangement of the cylinders was the same in both huts. The location of sucrose in relation to the LMs differed in each hut. The contextual stimuli surrounding the location of the hut set the occasion for the correct reinforced response relative to the LMs in the hut. When tested without sucrose present, the bees spent most of their time searching the area where the sucrose had been during training in each specific hut. These contextual cues were able to set the occasion for a specific spatial response. However, their procedure did not allow for the testing of transfer, which is an important feature of an OS.

In a similar spatial occasion setting procedure that did allow for transfer, Leising et al. (2015) trained pigeons with visual LMs presented on a touchscreen and measured pecks to locations on the screen. In this procedure, the same LM (a) was paired on separate trials with two OSs (X and Y), such that the spatial response-reinforcer relationship in the presence of the LM was unstable across trials without reference to the OS. Stability refers to the variance of a LM's vector (distance and direction) to the reinforced goal location across trials. Responding to the left of the goal location was reinforced during $\leftarrow Xa+$ trials and responding to the right of the goal location was reinforced on $Ya\rightarrow+$ trials. Additional trials included $a-$ and $b-$ alone, a second occasion setting pair ($\leftarrow Zb+$) in which responding to the left was reinforced, as well as a LM trained alone ($\leftarrow c$) with responding to the right reinforced. By the end of training the pigeons responded more to a on Xa trials than to a on a alone trials, and X and Y were able to control the location of responses on trials with a . The number of responses on a transfer trial with Yb was higher than on b alone trials, but incomplete relative to original training (Test 1). With regard to spatial control, the LM and not the OS, controlled the location of responses. The OS activated the appropriate response-reinforcement relationship for the LM, which is consistent with

previous research on occasion setting (Bonardi, Bartle, Jennings, 2009). The OSs were unable to alter the direction of responding during trials with the non-modulated LM c .

An additional transfer test (Test 3) of Z paired with a was conducted in Leising et al. (2015). In the Za transfer test, the OS was paired with a LM that was unstable during training (on half of the trials reinforcement was presented for responses to the left, and to the right on the remaining trials). Consequently, if Z simply modulated whether responding occurred to a then pigeons should have responded equally to both sides of a . Pigeons instead responded reliably in the direction associated with Z during training (responding was reinforced to the left of b when paired with Z). In fact, this test represents the only instance of complete transfer of both number of responses and spatial control out of five tests previously reported.

In another spatial occasion setting procedure, Cleland et al. (2017), pigeons were trained in a touchscreen spatial task with four occasion setting trials. During trials of $\leftarrow Wa+$ responding to the left of a resulted in reinforcement, while during trials of $Xa+\rightarrow$ responding to the right of a resulted in reinforcement. Another LM (b) was paired with Y and Z , with the OS's indicating opposite directions of reinforcement when paired with b . There were also three LM alone trials, $a-$, $b-$, and $\leftarrow c+\rightarrow$. On trials of c , 50% of the trials required responding to the left of c to obtain reinforcement and the other 50% required responding to the right of c . After training, transfer tests revealed that the number and spatial location of responses during a LM paired with the same OS as in training did not differ reliably from the OS paired with a different, modulated LM (Wb and Ya).

After this training, Cleland et al. (2017) altered the role a . This LM was retrained so that a was spatially informative on its own. Cleland et al. (2017) utilized the same pigeons and training with b to test the degree to which the spatial stability of LM a influenced successful

transfer. Retraining with a was intended to establish it as a non-modulated, stable LM by presenting training trials of $a \rightarrow +$ in which responding to the right was reinforced. The pigeons continued to be presented with training trials of $Yb \rightarrow +$ and $\leftarrow Zb+$. Subsequent tests with a revealed reduced, but reliable modulation of spatial location by the formerly trained OS (W), but no modulation of spatial location during transfer with a different OS (Y). After retraining of $\leftarrow a+$, responding during transfer tests of Ya was in the direction signaled by a , not the OS, which replicated the findings of Leising et al. (2015). Tests of OSs previously trained with a (Wa and Xa), however, were no different from the unaltered OS-LM pairs ($Yb \rightarrow$ and $\leftarrow Zb$). This indicates that spatial responding in this task was not driven by the OS as an excitatory stimulus or by the LMs alone, but rather, by the OS modulation of the response-reinforcer spatial relationship for each LM. Further, when the LM alone had a stable response-reinforcer spatial relationship it disrupted the OSs ability to control spatial responding. Lastly, transfer was altered by the change in training history that was previously shared by LMs a and b .

Experiment 1a

Leising et al. (2015) found that an OS can control spatial responding to a LM even if the LM's relationship to reinforcement is unstable and unreliable, if that LM is proximal to reinforcement. Proximity is a spatial measure that refers to the distance between a LM and the location of reinforcement. Stability is another spatial measure that refers to the variability or consistency in the LM's distance and direction relative to the location of reinforcement. Reliability is a non-spatial measure that refers to the probability that reinforcement will occur in the presence of the LM. Exp. 1a examined if a LM can control spatial responding in the presence of an OS that has a spatially unstable relationship with reinforcement. In Exp. 1a, pigeons were trained on a spatial occasion setting task similar to that of Leising et al. (2015) and Cleland et al.

(2017). Pigeons were trained to peck to the right or to the left of a LM (i.e., a colored square) embedded within an OS (i.e., a colored background). One OS was unstable in that the OS did not always give stable directional information about the location of reinforcement relative to the LM. In Exp. 1a, the direction of reinforced responding was to the left and right of LMs *a* and *b*, respectively, when paired with one OS (*W*), but when those same LMs (*a* and *b*) were paired with two different OSs (*X* and *Y*) the location of reinforcement was reliably signaled by the OS, left or right (reversed relative to when paired with *W*). This training was intended to result in an unstable OS (*W*) and two stable OSs (*X* and *Y*).

Previous research (Leising et al., 2015, Exp. 1) found that pigeons can learn to respond to the right on trials of $Xa \rightarrow +$ and to the left on trials of $\leftarrow Wa +$. On these trials, *a* is highly contingent with reinforcement in that it was always reinforced when paired with the OSs, but unstable in that the direction of reinforcement changed. Just as two OSs (i.e., *W* and *X*) can set the occasion for different responses in the presence of the same LM (i.e., *a*), we expected that two separate LMs (i.e., *a* and *b*) could control responding to the same OS (i.e., *W*). It was predicted that the instability of *W* would not impair its ability to elicit responding when compared to responding on $Xa-$ and $Yb-$ training trials, in which both the OSs had a stable relationship with reinforcement. However, we did expect differences at transfer. We predicted that a stable OS would control both the number of responses and spatial control to a greater extent than an unstable OS. An unstable OS would result in response competition in that it would elicit responding to both sides of the LM, and therefore responding would be depressed and there would be no spatial control by *W*. Another important procedural change from the procedures of Leising et al. (2015) and Cleland et al. (2017) was the exclusion of nonreinforced LM alone trials. It was predicted that the spatial ambiguity in the presence of the LM would be enough to

result in control over responding by the occasion setters, and that the presence of response ambiguity (i.e., whether or not reinforcement occurs when the LM is present) was not necessary.

Method

Subjects. Eight white Carneaux pigeons (*Columba livia*; Double T Farm, Iowa) served as subjects. Pigeons were maintained at 83-85% of their free-feeding weight and were individually housed in a colony with a 12 hr, light-dark cycle. Experimental procedures were conducted during the light portion of the cycle. They had free access to water and grit. All research was conducted in accordance with an approved TCU IACUC protocol.

Apparatus. Training and testing were conducted in a flat-black Plexiglas chamber with stimuli presented by computer on a colored LCD monitor (L1750, HP, Palo Alto, CA). Pecks to the monitor were detected by an infrared touch screen (EZ-170-WAVE, ezscreen, Houston, TX) mounted on the front panel. A food hopper (Coulbourn Instruments, Allentown, PA) capable of delivering mixed grain when activated was located in the center of the front panel, its access hole flush with the floor.

Stimuli. Visual stimuli fell into three categories: response locations, OSs, and LMs. Response locations were a row of eight squares that were 2 cm². These squares appeared in the center of the screen and were lined up horizontally across the screen. The OSs were colored backgrounds that surround the response locations and filled the remainder of the display. The background colors that served as OSs were solid red, blue, cyan, and orange. During occasion setting training, 1 of 6 possible response locations (i.e., locations 2-7) served as the selected position for the LM. When a response location was selected to be a LM, it was replaced with a LM, which was an image of a 4.8 cm (*l/w*) green (thin vertical white stripes), yellow (thick horizontal stripes), or pink (thick diagonal strips) box. Assignment of colors to LMs and OSs

was counterbalanced across subjects, though complete counterbalancing was limited due to the number of subjects. On any given trial, one location among response locations (2 – 7) served as the LM and one of the response locations (3 – 6) served as the goal. The spatial relationship between a LM, OS, and the hidden goal was consistent across trials, but the position of the LM and hidden goal varied. Pecks to the designated goal location resulted in the presentation of mixed grain. All experimental events were controlled and recorded with a desktop computer and coordinated via Microsoft Visual Basic 6.0 software.

Procedure. Pigeons were shaped via a mixed Pavlovian-instrumental procedure to peck a white circle displayed in the center of the monitor. After pecking to the circle was reliable, the response locations (8 horizontally aligned squares) were displayed in a row in the center of the monitor. Across trials a goal location, which resulted in reinforcement when pecked, was selected randomly without replacement from response locations 3-6. At the start of training, the response location that was the goal was indicated by filling that response location with white at full brightness (RGB = 255, 255, 255), while the remaining response locations were filled to 35% brightness. Within and across sessions the brightness of the goal was reduced to 50% brightness and eventually 35% brightness so that it was visually indiscriminate from the other response locations. Between and across sessions the goal was reinforced on a continuous reinforcement (CRF), Random-ratio (RR) 2, and then eventually an RR4 schedule (cf. Leising, Sawa, & Blaisdell, 2012). Subjects advanced to a new reinforcement schedule and a dimmer goal marker if they complete ten consecutive correct trials, and regress if they respond incorrectly on five consecutive trials.

Original Training. Training consisted of four occasion setting trials, $Wa \rightarrow +$, $\leftarrow Wb+$, $\leftarrow Xa+$, and $Yb \rightarrow +$ (see Table 1). A fifth training trial consisted of a LM alone, $\leftarrow c \rightarrow +$, during

which the goal location was to the right of c on 50 % of trials and to the left of c on the other half of the trials. A square serving as a LM was replaced with one of the three colored patterns described in the stimuli subsection of the procedure. On occasion setting trials the color of the entire display changed for a fixed-time 40 s interval. The color that filled the display served as the OS. The onset of the LM was delayed according to a variable-time 10 s schedule (ranging from 5 to 15 s in increments of 5 s) but terminated with the OS after 40 s. The LMs was presented for a mean duration of 30 s. The goal was always one location to the left or right of the LM, depending on the OS, and pecks to the goal location when the LM was present was reinforced according to the current reinforcement schedule until the trial terminated, meaning that the pigeons could be reinforced multiple times within a single trial.

The pigeons were reinforced for responding to the right when LM a was presented with the OS W ($Wa \rightarrow +$), but to the left when W was presented with LM b ($\leftarrow Wb +$). These trial types were hypothesized to result in the OS W being highly contingent with reinforcement but unstable in its spatial relationship to reinforcement. The pigeons also received trials with the OS X and LM a during which pigeons were reinforced for responses to the left of a ($\leftarrow Xa +$), as well as trials with the OS Y paired with LM b during which responses to the right of b were reinforced ($Yb \rightarrow +$). This training resulted in X and Y being highly contingent relationship with reinforcement, as well as a stable spatial relationship with reinforcement relative to the LM it was paired with. This training paired LMs b and a in an unstable spatial relationship with the goal across trials with different OSs. This was predicted to create ambiguity as to where to respond in the presence of a and b , forcing the pigeons to learn about the OSs. Across the experimental phases, responses to the hidden goal location resulted in 3 s of access to mixed

grain in the hopper. The number of responses needed to initiate reinforcement was dependent on the reinforcement schedule.

After a pigeon completed two consecutive sessions during which the goal was unmarked and responses were reinforced on a RR 4 schedule of reinforcement, as well as met the performance criteria of having responded correctly on 80% of occasion setting trials, the pigeon was eligible to be advanced to testing. However, to ensure that pigeons were matched in exposure to the Exp. 1 training trials before moving them on to retraining in Exp. 2, had a partner (yoked) that was tested after the same number of sessions. If one pigeon in the pair took longer to reach criteria, the other pigeon continued to train until both had met the criteria before moving to testing. Sessions consist of 60 trials with ten presentations of each trial type per session.

Testing. Pigeons were tested over two sessions with one day of training between test sessions. A test session consisted of (a) twelve blocks of an equal number of reinforced training trials ($Wa \rightarrow +$, $\leftarrow Wb+$, $\leftarrow Xa+$, $Yb \rightarrow +$, and $\leftarrow c \rightarrow +$), and (b) one block of eleven consecutive non-reinforced test trials. $c-$ trials were always 30 s in duration, while occasion setting trials terminated after 40 s. During a test session, the second to last block of training trials were replaced with nonreinforced testing trials. During a test session, the pigeons were presented with one non-reinforced test trial of the previously trained trials ($Wa-$, $Wb-$, $Xa-$, $Yb-$, and $c-$), as well as transfer trials that consisted of pairing an OS with a LM that it had not been paired with during training ($Wc-$, $Xc-$, $Ya-$, $Xb-$, $Wd-$, and $Yd-$). The order of test trials each day was counterbalanced across all subjects on both testing days. See Table 1 for a list of all trial types presented during testing. Similar to the procedure of Cleland et al. (2017), d was a novel LM that tested the ability of the OSs to transfer responding to a novel LM. The OS was present at the onset of the trial and the LM appeared 10 s into the trial. Both the OS and LM co-terminated at

40 s. The number of pecks and the location of pecks in relation to the LM was measured during all test trials.

Statistical Analysis for Number of Responses. The number of responses for each trial type was calculated by summing all pecks detected within the eight response locations. Before all analyses a two-way repeated measures analysis of variance (ANOVA) was conducted with Day (test day 1 and test day 2) and Trial type (*Wa-*, *Wb-*, *Xa-*, *Yb-*, *c-*, *Ya-*, *Xb-*, *Xc-*, *Wc-*, *Yd-*, and *Wd-*) as repeated measures on the number of responses. If there was no effect of Day and no interaction of Day by Trial type, all subsequent analyses used the average number of responses across both days of testing.

To examine whether or not there was response control on testing trials, single sample *t*-tests were conducted to test the average number of responses for each trial type against zero. To examine if excitatory strength differed across trial types, planned comparisons were used to compare the number of responses across different trial types (trained unstable OS: *Wa-* and *Wb-*, trained stable OS: *Xa-* and *Yb-*, LM alone: *c-*, transfer with stable OS: *Ya-* and *Xb-*, transfer to trained LM: *Xc-* and *Wc-*, and transfer to a novel LM: *Wd-* and *Yd-*) for those trials that are found to have response control.

Statistical Analysis for Spatial Difference Score. A spatial difference score of the proportion of responses was calculated for each trial type to examine where the pigeons pecked. To calculate proportion of pecks, pecks at the location to the immediate left of the LM, the LM itself, and to the immediate right of the LM were separately divided by the sum of pecks to all locations. From this, a spatial difference was calculated by subtracting the proportion of pecks to the right of the LM from the proportion of pecks to the left of the LM.

Before all analyses a two-way repeated measures analysis of variance (ANOVA) was conducted with Day (test day 1 and test day 2) and Trial type (*Wa-*, *Wb-*, *Xa-*, *Yb-*, *c-*, *Ya-*, *Xb-*, *Xc-*, *Wc-*, *Yd-*, and *Wd-*) as repeated measures on the number of responses. All subsequent analyses used the average difference score across both days of testing.

To examine whether or not there was spatial control on testing trials, single sample *t-* tests were conducted to test the spatial difference score for each trial type again zero. Of those trials on which responding does differ from zero, the strength of spatial control was compared across different trial types (trained unstable OS: *Wa-* and *Wb-*, trained stable OS: *Xa-* and *Yb-*, LM alone: *c-*, transfer with stable OS: *Ya-* and *Xb-*, transfer to trained LM: *Xc-* and *Wc-*, and transfer to a novel LM: *Wd-* and *Yd-*) using paired sample *t-* tests on the absolute value of the difference score.

Table 1: Design of Experiment 1a

Train	Test					
<i>Wa</i> → ← <i>Wb</i> ← <i>Xa</i> <i>Yb</i> → ← <i>c</i> →	Previously Trained	Stable-Unstable Modulated	Stable-Unstable	Unstable-Unstable	Stable-Novel	Unstable-Novel
	<i>Wa</i> →- ← <i>Wb</i> - ← <i>Xa</i> - <i>Yb</i> →- ← <i>c</i> →-	<i>Ya</i> - <i>Xb</i> -	<i>Xc</i> -	<i>Wc</i> -	<i>Yd</i> -	<i>Wd</i> -

Note. The columns indicate occasion setting training and testing trials. The arrows indicate the direction of reinforced responses relative to the landmark during training trials. The “-“ sign indicates no opportunity for reinforcement.

Results

Six of the pigeons were moved to testing after an average of 121 sessions of training ($SD = 30.25$). Two pigeons did not meet the criteria to advance to testing after an average of 263.50 sessions ($SD = 2.12$) and were therefore removed from the experiment.

For the number of responses, there was no effect of Day, $F(1, 5) = .01, p = .91$, and no interaction of Day by Trial type, $F(10, 50) = .41, p = .94$. The same result was found for the difference scores, with no effect of Day, $F(1, 5) = .77, p = .42$, and no interaction of Day by Trial type, $F(10, 50) = .49, p = .89$. Due to there being no effect of Day, averages across both days were used for all subsequent analyses.

Number of Responses.

Response control. Both previously trained occasion setting trials with LM b , $Wb-$ ($M = 27.42, SE = 7.47$) and $Yb-$ ($M = 24, SE = 5.68$), elicited more responding than zero, $ts(5) \geq 3.67, ps \leq .01$. Responding on trials of $Wa-$ ($M = 18.33, SE = 6.4$) was also greater than zero, $t(5) = 2.87, p = .035$, as was responding on trials of $c-$ ($M = 21, SE = 6.39$), $t(5) = 3.29, p = .022$. The only trained trial type that did not elicit responding greater than zero was $Xa-$ ($M = 13.42, SE = 8.06$), $t(5) = 1.67, p = .16$. Of the transfer trials, responding on trials of $Xb-$ ($M = 21.42, SE = 5.73$), $Yd-$ ($M = 5.83, SE = 1.87$), and $Wd-$ ($M = 8.08, SE = 2.21$) was greater than zero, $ts(5) \geq 3.11, ps \leq .03$. No other transfer trials elicited responding different from zero, $ts(5) \leq 2.12, ps \geq .09$. See Figure 2. See Table 2 for a list of all means and standard errors of the mean.

Between trial response control. Planned comparisons were conducted to compare across trial types for those trial types that did elicit responding greater than zero. All comparisons were made between trial types that signaled reinforcement in the same direction, ruling out any

differences based on a side bias. We predicted that the previously trained unstable OS trials would result in an equal amount of responding compared to the previously trained stable OS trials. Indeed, responding on the previously trained unstable OS trial *Wa-* did not differ significantly from trials of the previously trained stable OS *Yb*, $t(5) = 1.4$, $p = .22$. Comparing the previously trained trials to transfer trials, we predicted that there would be transfer of occasions setting. The trained unstable OS trial (*Wb-*) did not elicit significantly more responding than transfer trials with stable OS (*Xb-*), $t(5) = -.65$, $p = .55$. This was consistent with past research in which transfer to a previously modulated LM was complete relative to the responding on the previously trained OS trials (Leising et al., 2015). However, the previously trained trial with an unstable OS (*Wb-*) elicited marginally more responding than on trials of *Wd-*, $t(5) = 2.38$, $p = .06$. However, transfer trials with an unstable OS paired with a novel LM (*Wd-*), did not elicit less responding than transfer trials of a stable OS with a novel LM, (*Yd-*), $t(5) = 1.17$, $p = .29$.

Spatial Responding.

Spatial control. Spatial control was strongest on previously trained trials, except for on trials of *Xa-* (see Figure 3). The spatial difference score for the training trials with an unstable OS, *Wa-* ($M = -.27$, $SE = .08$) and *Wb-* ($M = .41$, $SE = .11$), differed significantly from zero, $t(5) \geq 3.51$, $ps \leq .017$. Spatial responding on trials of *Yb-* ($M = -.58$, $SE = .22$) also elicited spatial control stronger than that of a spatial difference score of zero, $t(5) = 6.45$, $p > .01$. The other previously trained stable OS trials (*Xa-*) ($M = .07$, $SE = .22$), however, did not elicit responding strongly in either direction resulting in a difference score of zero, $t(5) = .31$, $p = .77$. The only transfer trial on which spatial control was marginally higher than zero was on trials of

Xb- ($M = .29$, $SE = .12$), $t(5) = 2.34$, $p = .07$. See Table two for a list of all mean difference scores and standard errors of the mean.

Between trial spatial control. Planned comparisons were conducted to compare across trial types for those trial types that did elicit spatial control stronger than a difference score of zero. The difference score for the previously trained trials with an unstable OS (*Wa-*) and the previously trained trials with a stable OS (*Yb-*) did significantly differ, $t(5) = 4.82$, $p < .01$, with *Yb-* eliciting stronger spatial control. Previously trained trials with the unstable OS (*Wa-*) resulted in weaker spatial control than previously trained trials with a stable OS (*Yb-*). To test for spatial control between two trials that elicited responding in different directions, responding on the previously trained trials *Wb-* and *Yb-* was compared. *Wb-* and *Yb-* resulted in significantly different spatial control, $t(5) = 5.76$, $p < .01$. Pigeons demonstrated no difference in spatial control on previously trained *Wb-* trials when compared to *Xb-* transfer trials, $t(5) = .82$, $p = .45$.

Table 2

Mean and standard errors of the mean for the number of responses for each trial type for Exp. 1a.

Trial Type	<i>M</i>	<i>SE</i>
<i>Wa-</i>	18.33*	6.4
<i>Wb-</i>	27.42*	7.47
<i>Xa-</i>	13.42	8.06
<i>Yb-</i>	24*	5.68
<i>c-</i>	21*	6.39
<i>Ya-</i>	11.37	6.75
<i>Xb-</i>	21.42*	5.73
<i>Xc-</i>	5.25	2.93
<i>Wc-</i>	6.58	3.1
<i>Yd-</i>	5.83*	1.87
<i>Wd-</i>	8.08*	2.21

*indicated significantly different than zero, $p \leq .05$.

Table 3

Mean and standard errors of the mean for the difference scores for each testing trial type for Exp. 1a.

Trial Type	<i>M</i>	<i>SE</i>
<i>Wa-</i>	-.17*	.08
<i>Wb-</i>	.41*	.11
<i>Xa-</i>	.07	.22
<i>Yb-</i>	-.58*	.09
<i>c-</i>	-.19	.13
<i>Ya-</i>	-.15	.1
<i>Xb-</i>	.29	.12
<i>Xc-</i>	.13	.09
<i>Wc-</i>	-.29	.12
<i>Yd-</i>	-.07	.09
<i>Wd-</i>	.25	.14

*indicated significantly different than zero, $p \leq .05$.

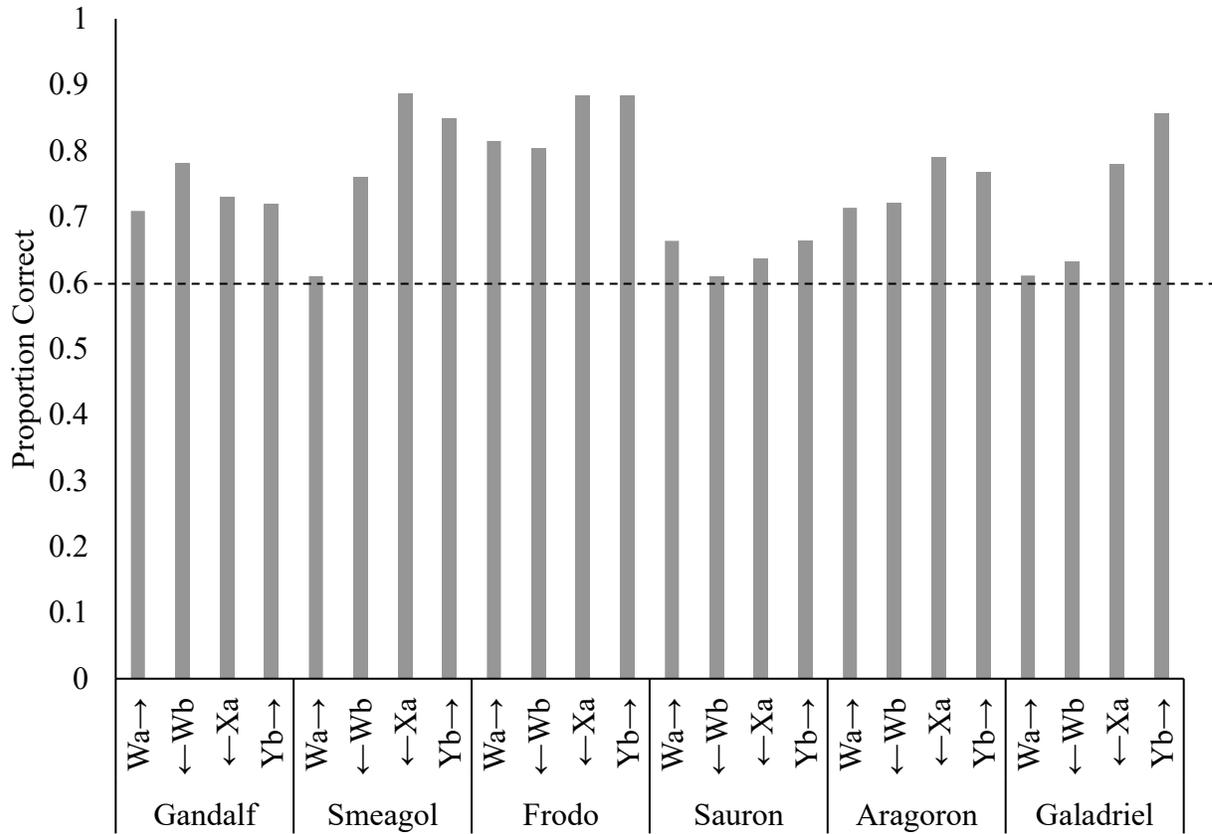


Figure 1. The proportion correct for each trial type for each bird during training for Exp. 1a. This figure consists of the proportion of correct responding across the last ten sessions before the pigeon advanced to testing. The criteria to advance to testing was 60% accuracy on all OS trials. *W*, *Y*, and *Y* refer to OSs, while *a* and *b* were LMs.

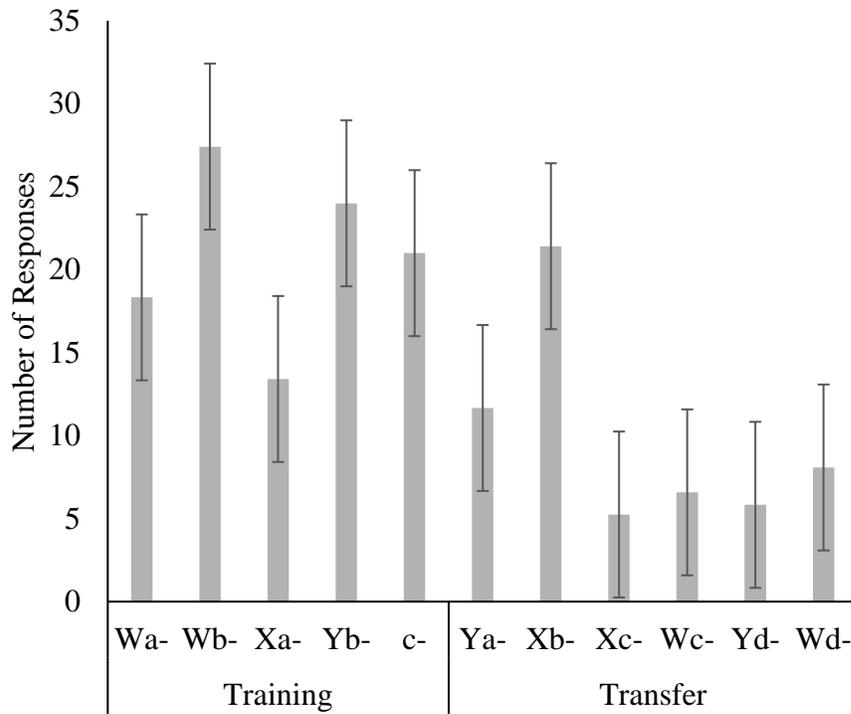


Figure 2. The mean number of responses at test for Exp. 1a. W, X, and Y refer to the OSs, while a, b, and c are LMs. All test trials were nonreinforced. During training test trials, previously training OS and LM alone trials were presented. On transfer trials, the trained OSs were paired with LM they had not been trained with. Error bars represent the standard error of the mean.

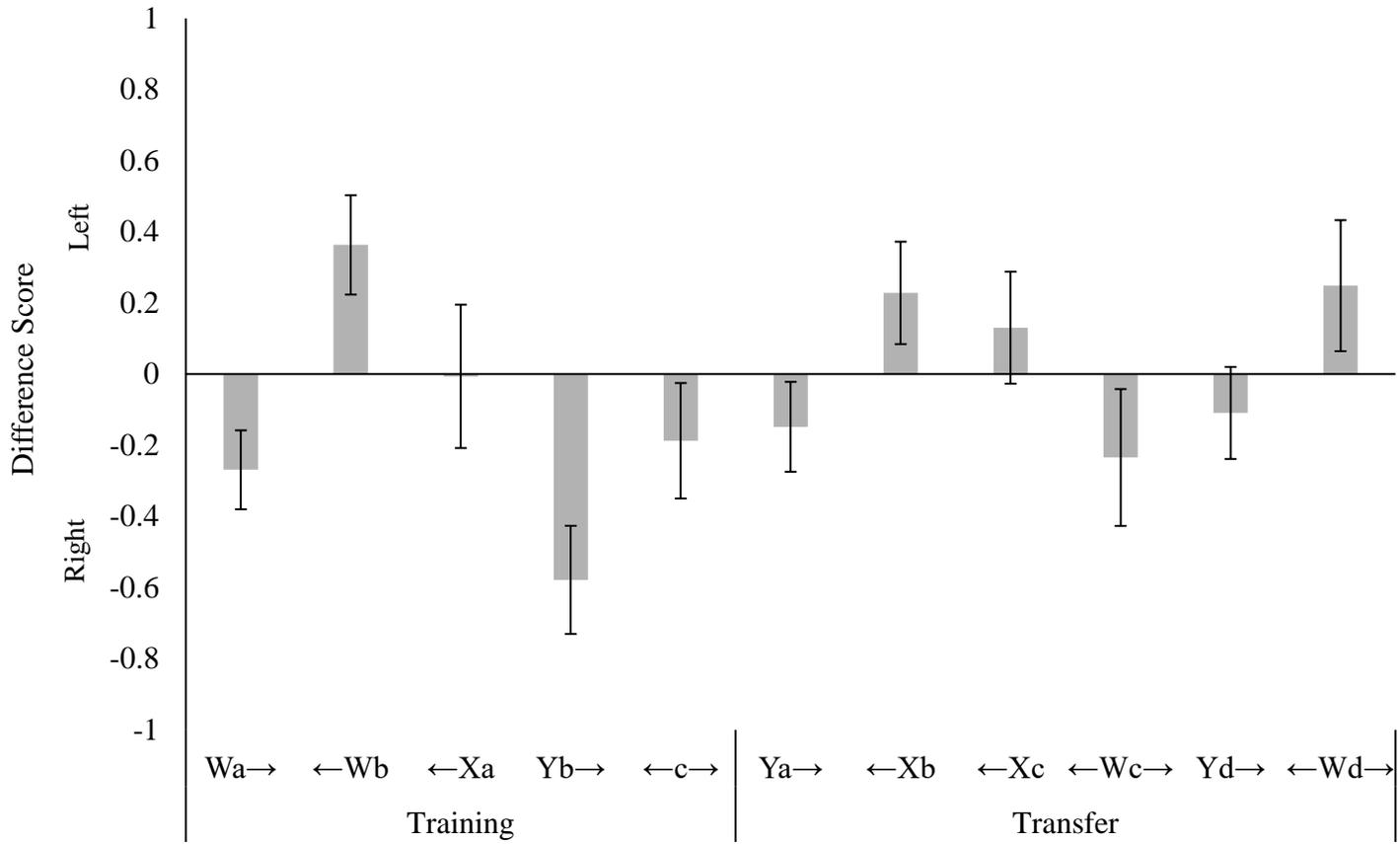


Figure 3. The mean difference score for Exp. 1a. W, X, and Y refer to the OSs, while a, b, and c are LMs. The difference score was calculated by subtracting the proportion of pecks to the left of the LM from the proportion of pecks to the right of the LM. Error bars represent the standard error of the mean.

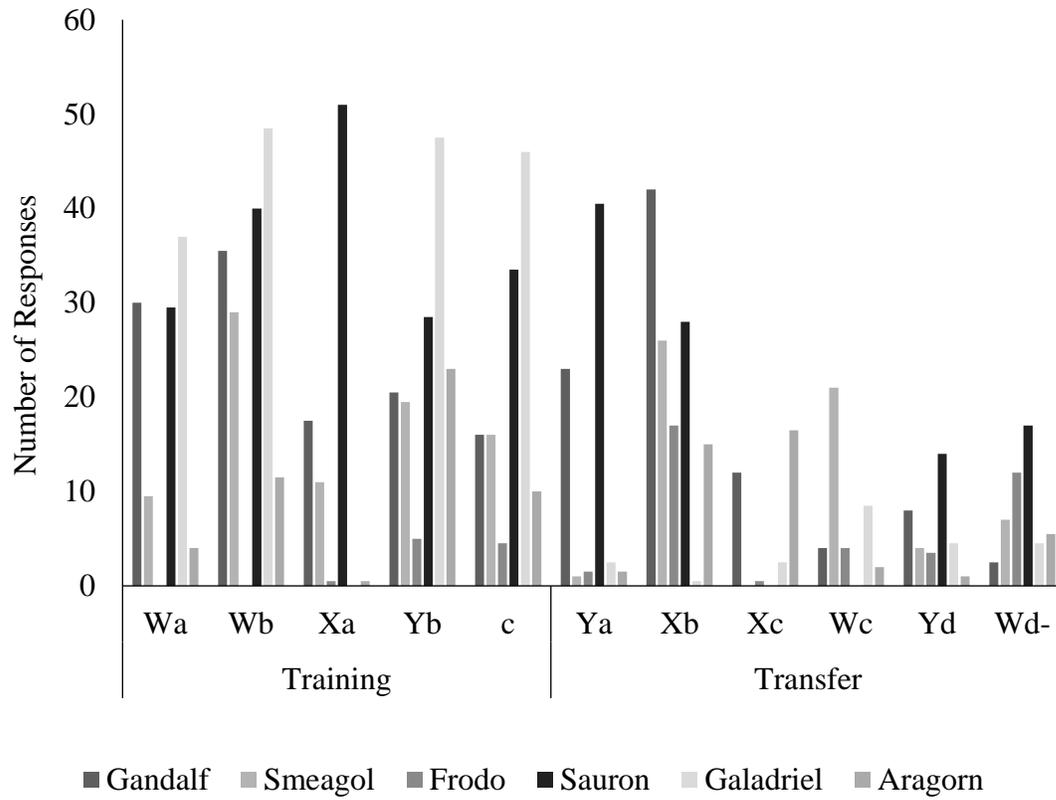


Figure 4. The individual number of responses at test for Exp. 1a. W, X, and Y refer to the OSs, while a, b, and c are LMs. All test trials were nonreinforced. During training test trials, previously training OS and LM alone trials were presented. On transfer trials, the trained OSs were paired with LM they had not been trained with.

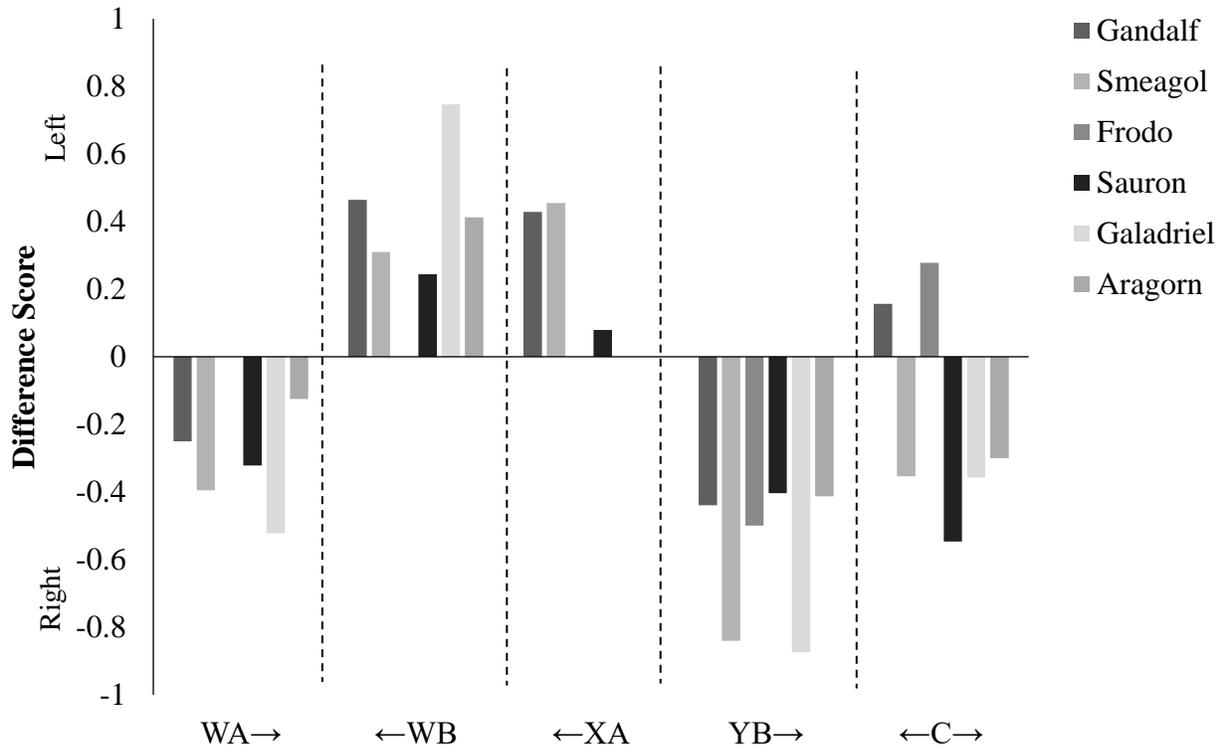


Figure 5. Individual difference scores for trained trials in Exp. 1a. All trials were nonreinforced testing trials. W, X, and Y refer to the OSs, while a, b, and c are LMs. The difference score was calculated by subtracting the proportion of pecks to the left of the LM from the proportion of pecks to the right of the LM. Error bars represent the standard error of the mean.

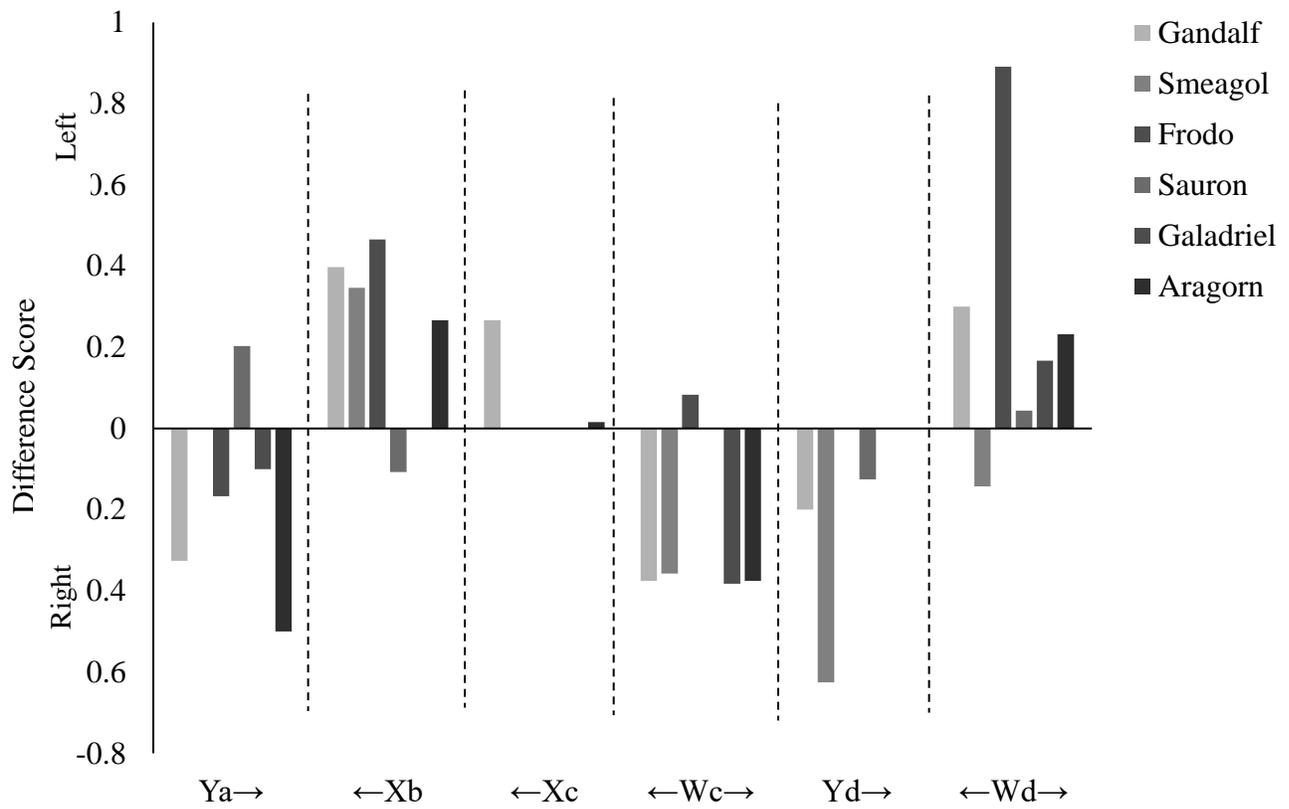


Figure 6. Individual difference scores for transfer trials in Exp. 1a. All trials were nonreinforced testing trials. W, X, and Y refer to the OSs, while a, b, and c are LMs. The difference score was calculated by subtracting the proportion of pecks to the left of the LM from the proportion of pecks to the right of the LM. Error bars represent the standard error of the mean.

Discussion

As expected, both the number of responses and the difference scores were greater than zero on previously trained OS trials of *Wa-*, *Wb-*, and *Yb-*. Responding on trials of *Xa-* did not differ from zero. At test, the pigeons did not express any learning to *Xa*. This unstable OS was able to elicit the equivalent excitatory strength as a stable OS when paired with an unstable LM. Also, the previously trained unstable OS (*Wa-*) did not elicit less responding than the previously trained stable OS (*Yb-*). This seems contrary to the above finding that not all trained occasion setting trials elicited response control and spatial control. Spatial accuracy was weaker on trials with a previously trained unstable OS (*Wa-*) than on trials with the previously trained stable OS that did acquire spatial control over its trained LM (*Yb-*). This suggests that although the unstable OS *W* and stable OS *Y* controlled excitatory responding equally well, the stable OS *Y* controlled spatial responding to a stronger degree.

Unexpectedly, responding was not different from zero on the previously trained OS trials of *Xa-*. *X* did not elicit responding when paired with *a*. There was also no spatial control by *Xa*. Both responding and spatial control were greatest on trials of *Yb-*, followed by trials of *Wb-*. These two trials elicited spatial responding in opposite directions when paired with *b*. This finding was supported by the planned comparisons testing the difference scores on *Yb-* trials against that on *Wb-*, as well as the findings that both trial types elicited a spatial difference score significantly higher than zero. The bird's inability to learn all of the trained occasion setting trials differs from the findings of Cleland et al. (2017) in which four different OSs (*W*, *X*, *Y*, and *Z*) were trained to developed both response control and spatial control over two different LMs (*a* and *b*). An important difference that could account for this is the stability of the OSs that in Cleland et al. (2017), the four OSs provided stable spatial information about where to respond in

relation to a spatially unstable LM. It seems likely that the addition of an unstable OS made the task more difficult, and therefore the pigeons were unable to reach the same level of accuracy as was seen in Cleland et al. (2017).

Another explanation for this difference could be the exclusion of nonreinforced *a*- and *b*- trials. These trials would have resulted in the pigeons experiencing sessions in which there was partial reinforcement. Partial reinforcement would likely have resulted in pigeons that were less susceptible to the effects of extinction at test. This difference would account for low responding at test, with some birds not responding on multiple test trials. The differences found between the current experiment and Cleland et al. (2017) could be the result of the affect that the conditions at test had on the pigeons. Some support for this hypothesis is the training data. All pigeons reached the criteria of correct responding on 60% of *Xa* trials before moving on to test. The pigeon's demonstrated acquisition of *Xa* during training, but the conditions of test may have disrupted responding on these test trials.

Looking at transfer, trials with a stable OS (*Xb*-) did not elicit more responding than trials of the previously trained unstable OS trial (*Wb*-) on which there was response control. This could suggest transfer of control over LM *b* by the stable OS *X*. However, responding on trials of *Xa*- showed no response control by *X*. This suggests that *X* had acquired no excitatory value or spatial control and that transfer on trials of *Xb*- is not the result of *X*'s excitatory value. There are at least two possible explanations. First, transfer is more likely coming from a generalization decrement to *Xb*- from *Yb*-. *Yb*- was found to be highly excitatory. The spatial difference score on transfer trials of *Xb*-, however, suggests responding not in the direction indicated by *Y* on transfer trials of *Xb*-, but rather in the direction trained by *X*. *X* had no spatial control on its previously trained trials (*Xa*-). It seems unlikely that this spatial transfer is actually the result of *X*

modulating a spatial response to b or generalization from Yb . The second explanation is that it is possible that the pigeons have acquired on trials of Yb - and Wb - as a result of learning the configuration of Yb and then responding differently to everything that was not Yb . This would result in generalization of excitation from Wb to Xb . This explains both the poor acquisition of occasion setting trials paired with LM a , as well as transfer to Xb and no transfer to Ya . LM b formed an important part of the Yb and Wb configurations, resulting in less generalization from Yb and Wb to Ya .

On transfer test with LM c (Xc - and Wc -), responses did not differ from zero in both the number of responses as well as the spatial difference score, indicating no transfer. Also, on test trials of transfer to a novel LM (Wd - and Yd -), there was no difference between Wd - and Yd - in the degree of excitatory transfer, however, responding on trials of Wd - was lower than responding on the previously trained OS (Wb -). These results indicate that spatial stability did not affect transfer of response control, and confirm that transfer with a novel LM results in less responding than the previously trained trials (Leising et al., 2015). Also, there was no transfer of spatial control when W and Y were paired with d .

For spatial control, the stability of the OS did affect spatial accuracy, with the unstable OS (W) controlling the location of responding relative to b to a lesser degree than on trials with the stable OS (Xb -). By comparing the finding of Exp. 1a to the findings of Cleland et al. (2017), it can be concluded that stability of the OS likely matters in terms of overall accuracy. The stability of the OSs likely affected how the OSs were learned about, resulting in transfer to only one of the two previously trained transfer trials.

Due to the small number of subjects, looking at the individual data for each pigeon has value. During testing of the previously trained trials, all pigeons that responded did so in the

direction indicated by $Wa-$, $Wb-$, and $Yb-$. However, on the previously stable OS trial $Xa-$, there was individual variation in both the number of responses and spatial control by $Xa-$ (see Figure 4). One pigeon responded the highest number of times on trials of $Xa-$, while two other pigeons responded fewer than three times. Looking at spatial control (see Figure 6), three of the pigeons responded to the left of $Xa-$ (the trained direction), while two responded in the opposite direction and one did not respond at all. This variation led to an average different score not above zero, indicating no spatial control at all. However, in reality there was some excitatory and spatial control on $Xa-$ trials, but this control was inconsistent across pigeons.

It is possible, these findings collectively suggest that the pigeons may also learn the retraining trials during Exp. 1b differently than expected. It was predicted that a hierarchical relationship between X and a -US would develop after training in Exp. 1a. The lack of learning to Xa suggests that this did not happen, and that rather, retaining in Exp. 1b will result in learning about X for the first time. Considering that the pigeons appeared to learn about the configuration of Yb in Exp. 1a and used this to solve the discrimination, it is likely that pigeons in both groups will continue to learn about the configurations of stimuli, rather than any hierarchical relationships between stimuli.

Experiment 1b

Rescorla (1986) found that posttraining manipulations of the excitatory value of the OS does not disrupt that OS's ability to modulate responding to a DS. Rescorla trained pigeons on two serial feature-positive pairings (i.e., $Lx+/Nx+/x-$) followed by posttraining manipulation of the OSs and DSs. The results showed that excitation of one of the OSs (e.g., $L+$) did not disrupt the OS's ability to modulate responding to the DS relative to an OS that had not undergone excitatory training. Experiment 1b is intended to replicate these findings within the spatial

occasion setting domain. Further, Exp. 1b examines the effect of posttraining manipulation of the stability of an OS, something that is not possible with non-spatial occasion setting tasks. Cleland et. al (2017) found that posttraining excitatory training of the LM only partially disrupted the trained OSs spatial control over that LM, but the LM no longer came under the control of the OS during transfer tests. Exp. 1b used a similar procedure, but the OS underwent posttraining excitatory training.

The same pigeons as in Exp. 1a served as subjects for Exp. 1b. Exp. 1b training directly followed Exp. 1a testing. For half of the pigeons (Group OS'), X was made into a spatial unstable OS (i.e., $\leftarrow Xb+/Xb\rightarrow+$), and for the other half of the pigeons (Group DS) X underwent excitatory training that resulted in X acquiring a spatially unstable relationship with reinforcement, but as a DS and not as part of an occasion setting pairing (i.e., $+ \leftarrow X \rightarrow +$).

It was expected that retraining of the OS as a kind of LM, after it had been trained in an OS pairing would be less disruptive of the OSs ability to modulate responding to a different LM when compared to retraining of the OS as an unstable predictor of the goal without the presence of a LM. Pigeons were hypothesized to learn about the relationship between X and a -US during Exp. 1a, and not any direct relationship between X and the location of reinforced responding. New learning about X and its modulatory ability over different LMs will be more similar to previous training with that OS and therefore more disruptive to any new learning than learning of the direct relationship between X and reinforcement. In the current experiment, retraining of X in Group OS' as an unstable OS (i.e., $\leftarrow Xb+/Xb\rightarrow+$) was expected to disrupt X 's ability to control responding on subsequent test trials of the previously trained Xa -. These results would suggest that OSs are stimuli that are different from a DS, in that manipulating the excitatory value of X as a DS will leave X able to modulate spatial responding to its previously trained LM.

Method

Subjects. Six white Carneaux pigeons (*Columba livia*; Double T Farm, Iowa) who had previously participated in Experiment 1a of this study served as subjects. Upon completing both days of testing for Experiment 1a, the pigeons were moved on to training for Experiment 1b. Pigeons were maintained at 83-85% of their free-feeding weights and were individually housed in a colony with a 12 hr light-dark cycle. They had free access to water and grit. Experimental procedures were conducted during the light portion of the cycle. All research was conducted in accordance with an approved TCU IACUC protocol.

Apparatus. The apparatus was identical to that of Experiment 1a. Training and testing will be conducted in a flat-black Plexiglas chamber with stimuli presented by computer on a color LCD monitor (L1750, HP, Palo Alto, CA).

Stimuli. Visual stimuli fell into three categories: response locations, OSs, and LMs. These stimuli were identical to those used in Exp 1b. Assignment of color to LMs and OSs remained consistent for a bird across Exp 1a and 1b. All experimental events were controlled and recorded using a desktop computer and coordinated via Microsoft Visual Basic 6.0 software.

Procedure. At the start of training, the location of the goal was marked with a white square at full brightness ($RGB = 255, 255, 255$), while the remaining locations were filled to 35% brightness. Within and across sessions the brightness of the goal was reduced to 35% brightness and responses at the goal were reinforced on a continuous reinforcement (CRF) and then a Random-ratio (RR) 2 schedule of reinforcement. Subjects advanced to a new reinforcement schedule and a dimmer goal marker if they complete correctly competed ten consecutive trials and regressed if they respond incorrectly on five consecutive trials.

Retraining. During retraining, the pigeons were split into two groups (Group OS' and Group DS) with three pigeons in each group.

For Group OS', the previously stable OS X was retrained to become an unstable OS. Retraining in Group OS' will consist of trials of $\leftarrow Xb+$, for which reinforcement was delivered if the pigeon pecked either one or two locations directly to the left of b , along with trials of $Xb\rightarrow+$ for which reinforcement was delivered when pigeons peck one or two locations to the right of b . The location of the goal was restricted to the four middle response locations. The OS preceded the LM by a variable-time 10 s schedule (ranging from 5 to 15 s in increments of 5 s), just as in Exp 1a. For the pigeons in Group DS, X was retrained to make it an unstable discriminative stimulus, $+ \leftarrow X \rightarrow +$, with no LM present. X no longer set the occasion for responding to a LM. Rather, X was directly reinforced, making it a discriminative stimulus rather than an OS. Due to the gap of time before the presentation of the LM during which pigeons in Group OS' could not receive reinforcement, in Group DS there was an average of 10 s (variable-time 10 s schedule ranging from 5 to 15 s in increments of 5 s) after the initial presentation of the OS during which no pecks were reinforced. Just as in Exp. 1a, the location of the goal was marked with a white square at full brightness. Within and across sessions the brightness of the goal was reduced until it was indistinguishable from the other response locations.

Testing. See Table 4 for a list of all trial types presented at testing. A test session consisted of (a) ten blocks of an equal number of reinforced training trials of $\leftarrow Xb+$ and $Xb\rightarrow+$ for pigeons in condition A and $+ \leftarrow X \rightarrow +$ for pigeons in Group DS, and (b) one block of four consecutive non-reinforced test trials. Over two sessions (with one normal day of training in the middle), the pigeons received two non-reinforced test trials of $Xa-$ and $Wa-$ during the second to last block of trials during that session. The order of the testing trials in a session remained

consistent across subjects and across days, with two *Xa-* trials followed by two *Wa-* trials. Trials terminated after 40 s. The number of pecks and the location of pecks in relation to the LM were recorded during all test trials.

Statistical Analysis of Number of Responses. Same as Exp. 1a.

Statistical Analysis of Spatial Control. Same as Exp. 1a, except pecks to the two locations to the left and the two locations to the right of the LM were also averaged to get total left and total right measures of pecks relative to the LM. This average was calculated because training in Exp. 1b resulted in reinforced responding both one and two away from the LM. From this average the proportion of pecks to the right and left were calculated by dividing the average pecks to the two locations on each side of the LM and dividing that by the total number of pecks to the two locations to the right and left of the LM and the LM itself. From this a difference score was calculated by subtracting the proportion of pecks to the left of the LM to the proportion of pecks to the right of the LM.

Table 4: Design of Experiment 1b

Retrain		Test
<u>Group OS'</u>	<u>Group DS</u>	
$\leftarrow Xb$	$\leftarrow X$	<i>Xa-</i>
$Xb \rightarrow$	$X \rightarrow$	<i>Wa-</i>
$\leftarrow \leftarrow Xb$	$\leftarrow \leftarrow X$	
$Xb \rightarrow \rightarrow$	$X \rightarrow \rightarrow$	

Note. The columns indicate occasion setting training and testing trials. The arrows indicate the direction of reinforced responses relative to the landmark during training trials. The “-“ sign indicates no opportunity for reinforcement.

Results

Pigeons were trained for an average of 77 sessions ($SE = 1.41$) before being advanced to testing.

A three-way repeated measures ANOVA with Day (1 and 2) and Trial type ($Xa-$ and $Wa-$) as repeated measures and Group (Group OS' vs. Group DS) was conducted on the number of pecks and difference score. There was no effect of Day, $F(1, 5) = .77, p = .422$, and no interaction of Day by Trial type, $F(1, 5) = 2.73, p = .16$, for the number of responses. For the difference score, there was no effect of Day, $F(1, 4) = .04, p = .846$, and no interaction of Day by Trial type, $F(1, 4) = .47, p = .53$. Due to this, responding was collapsed across Day for all subsequent analyses.

Number of Responses.

Response control. A two-way repeated measures ANOVA was conducted with Trial type ($Xa-$ and $Wa-$) as repeated measures and Group as the between subjects factor on the number of responses. There was no effect of Trial type, $F(1, 4) = 2.27, p = .207$, no effect of Group, $F(1, 4) = 5.72, p = .08$, and no interaction of Trial type by Group, $F(1, 4) = .23, p = .66$ (see Figure 8).

Single sample t -test were conducted to compare the number of responses for each trial type to zero. Both $Xa-$ ($M = 64.83, SE = 17.9$) and $Wa-$ ($M = 46.25, SE = 15.63$) elicited responding greater than zero, $ts(5) \geq 2.96, ps \leq .03$.

Spatial Responding.

Spatial control. A two-way repeated measures ANOVA with Trial type ($Xa-$ and $Wa-$) as the repeated measures and Group (Group OS' vs Group DS) was conducted on the difference score averaged across days. There was no effect of Group, $F(1, 4) = 1.05, p = .36$, no effect of

Trial type, $F(1, 4) = 4.42, p = .1$, and no interaction of Group by Trial type, $F(1, 4) = 1.3, p = .32$ (see Figure 11).

Single sample t -tests were conducted on the difference score for testing trials Xa - and Wa -. Since there was no effect of Group, difference scores were collapsed across Group. The difference score on test trials of Xa - ($M = -.03, SE = .14$) did not differ from zero, $t(5) = -.21, p = .84$. However, on test trials of Wa - ($M = -.24, SE = .06$) the average difference score was greater than from zero, $t(5) = -4.1, p = .01$, suggesting continued spatial control by W over a .

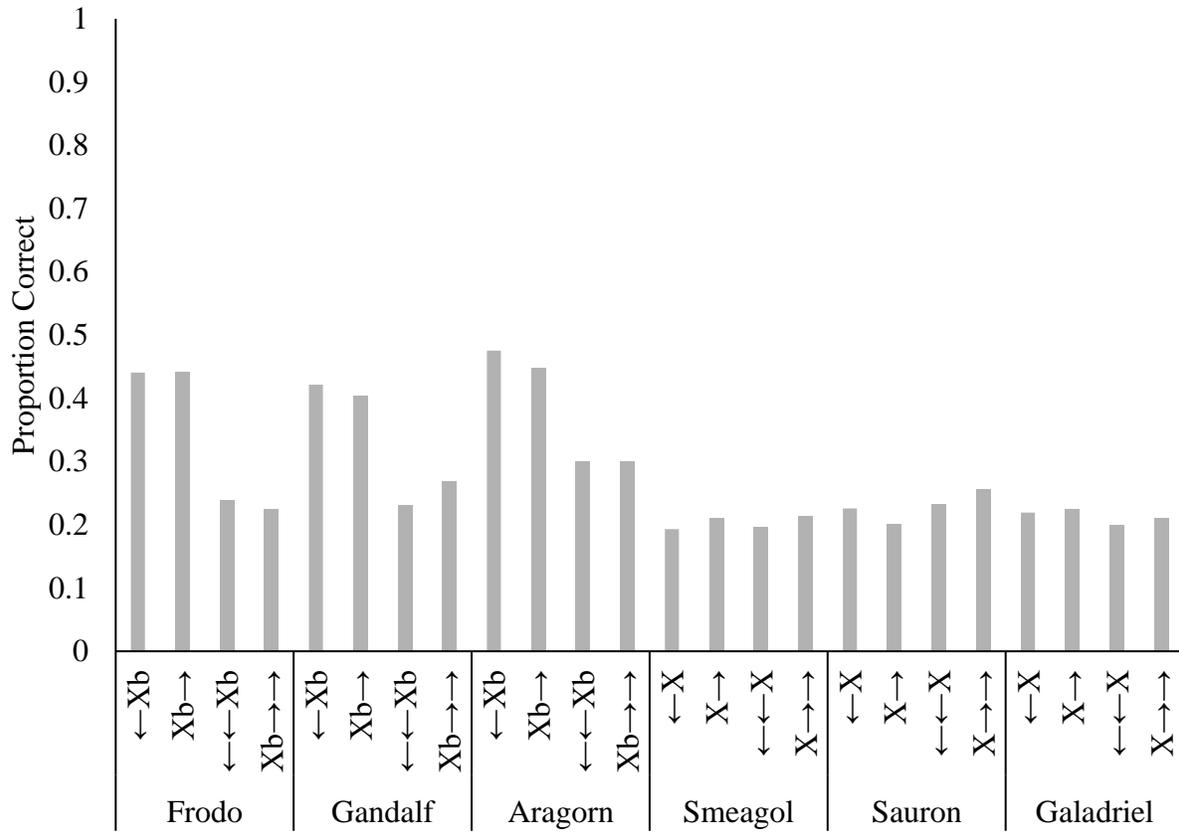


Figure 7. The proportion correct for each trial type for each bird during training for Exp. 1b. This figure consists of the proportion of correct responding across the last ten sessions before the pigeon advanced to testing. X refer to OSs, while b was a LM. Pigeons in Group OS' (Frodo, Gandalf, and Aragorn) were trained on OS trials in which Xb was made unstable, while pigeons in Group DS (Smeagol, Sauron, and Galadriel) were trained on trials in which X alone was made unstable.

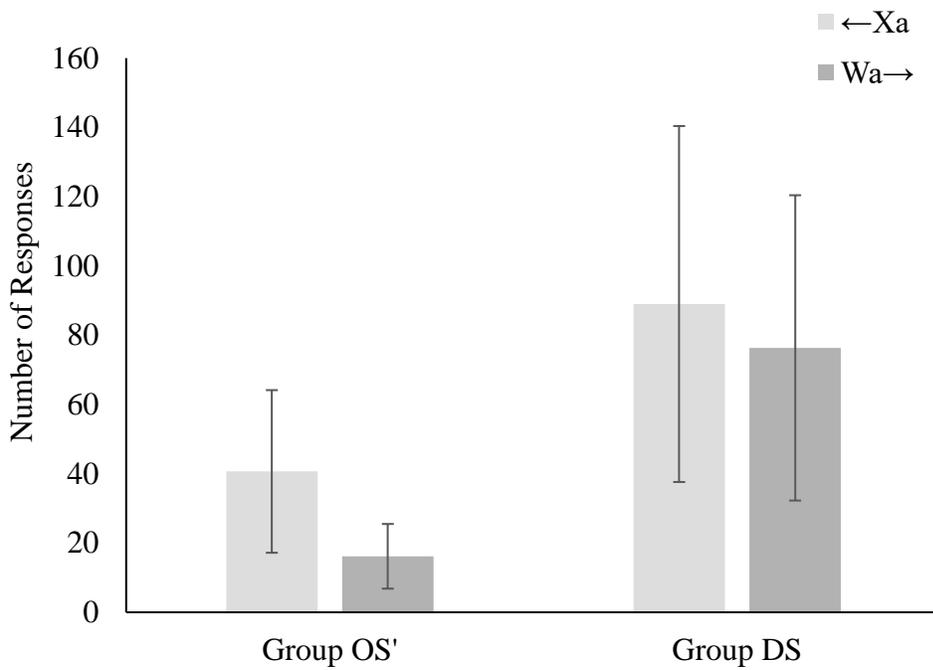


Figure 8. The mean number of responses for Exp. 1b. X and W are OSs, while a is a LM. Error bars represent the standard error of the mean.

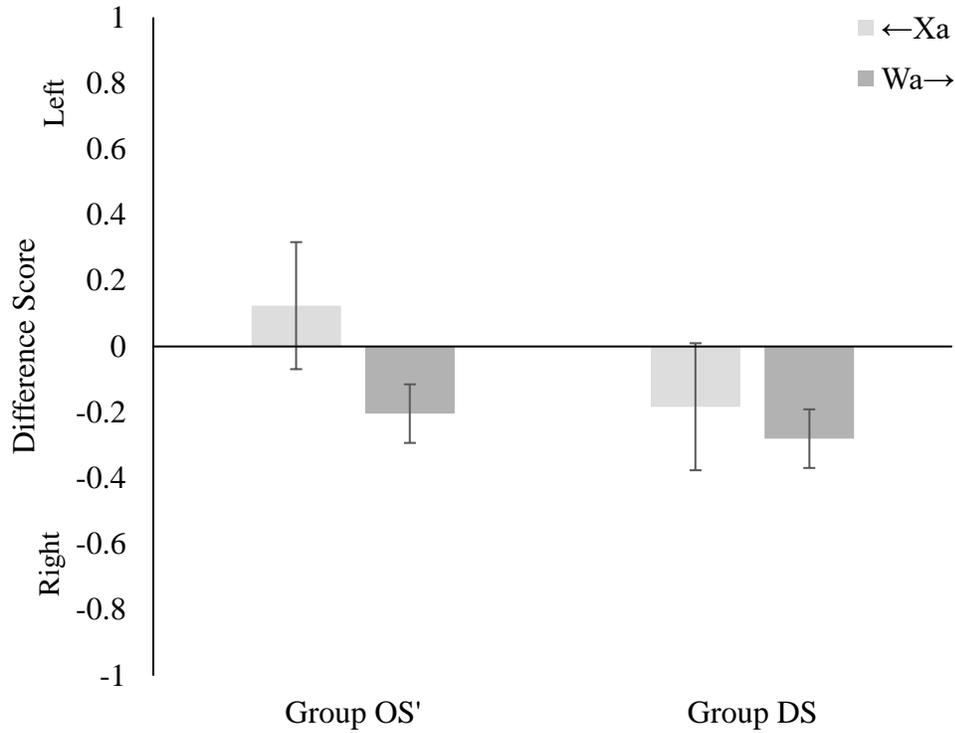


Figure 9. The mean difference score for Exp. 1b. The difference score was calculated by subtracting the proportion of pecks one and two locations to the left of the LM from the proportion of pecks one and two locations to the right of the LM. Pigeons were trained to peck to the left of *a* on *Xa* trials during Exp 1a. During 1b, *X* was made unstable for Group DS and *Xb* was trained as an unstable OS trial in Group OS'. Error bars represent the standard error of the mean.

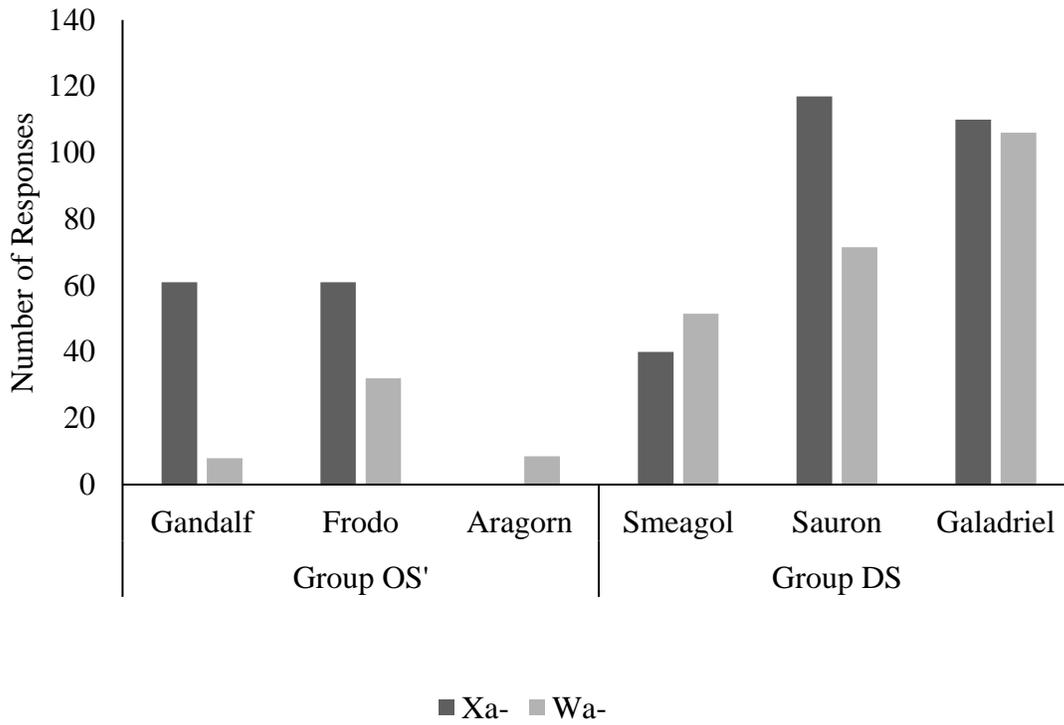


Figure 10. The individual number of responses at test for Exp. 1b. X and W refer to the OSs, while a is a LM. All test trials were nonreinforced.

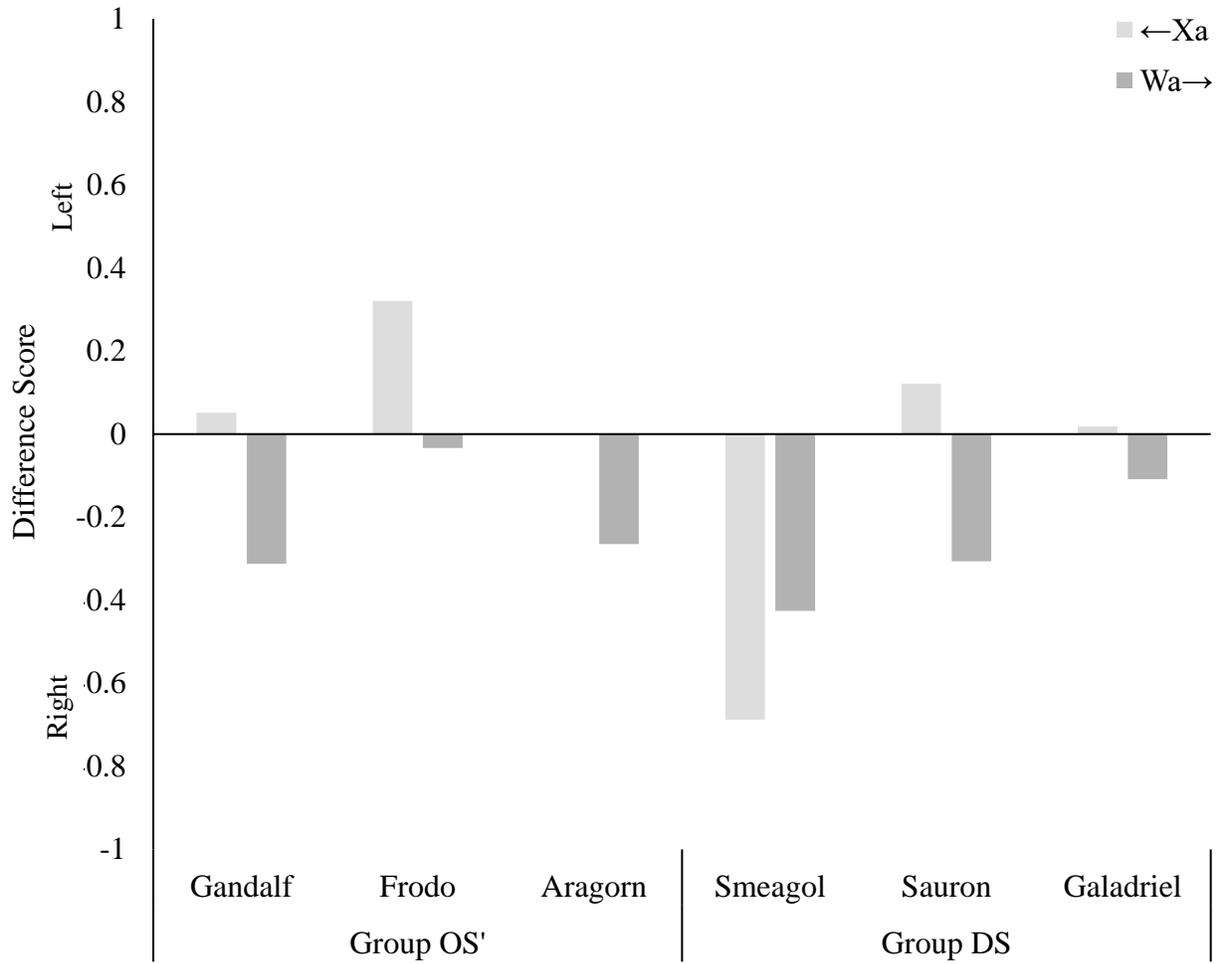


Figure 11. Individual difference scores for Exp. 1b. The difference score was calculated by subtracting the proportion of pecks one and two locations to the left of the LM from the proportion of pecks one and two locations to the right of the LM.

Discussion

Since there was no evidence of control of X over a , the retraining of X in Exp. 1b may have endowed that OS with the ability to control responding for the first time. Since Xa^- was never strongly acquired in Exp. 1a, it is not surprising that new training with X resulted in inaccurate performance on the original Xa^- trials during testing of Exp. 1b.

The results of Exp. 1b indicated only a marginal effect of group on excitatory responding, suggesting that retraining to make a previously stable OS an unstable OS with a different LM did not disrupt the original spatial responding to a greater degree than retraining a stable OS as a kind of unstable LM. After retraining, the OS X no longer controlled responding to LM a for pigeons in both Groups. Retraining X as both an unstable OS and an unstable discriminative stimulus disrupted X 's ability to modulate a spatial response to a . If X was an OS, these results would refute the original hypothesis that retraining of X as a DS would not disrupt its ability to release a specific spatial response in the presence of a , however, this hypothesis assumed hierarchical and not configural control. Retraining did not affect excitatory modulation, with pigeons responding equally to both Xa^- and Wa^- test trials. X controlled an excitatory response for both Groups, it just no longer controlled a specific spatial response in the presence of a . This is likely because retraining endowed X with a direct association to reinforcement in both groups due to pigeons learning about the configuration of Xb in Group OS' and X alone in Group DS. This excitation of X would generalize to Xa trials for both Group OS' and Group DS, as both groups learned about the relationship of the common element X to reinforcement. Of interest is the marginally significant difference in responding between Group OS' and Group DS in the number of responses at test. This may be the result of more generalization from X to Xa for Group DS. Perhaps it easier to ignore the addition of a LM as opposed to a LM being swapped

for a different one. However, Group DS also responding more on test trials of *Wa-*. This makes it unlikely that the increased responding relative to Group OS' on *Xa-* trials was the result of the retraining manipulations as the same effect was found across both trial types.

Retraining did not disrupt responding to *Wa-*. This training trial was absent during Exp. 1b training, and thus served as a comparison to account for forgetting. Despite several months with no training of *Wa-*, *W* still released a specific spatial response to *a*. This provides evidence that any disruption in responding on *Xa-* trials was the result of the retraining procedures and not the result of forgetting.

Again, due to the small sample size and the large amount of variation, it is worth examining the individual scores of each pigeon. Looking at the number of responses (see figure 7), pigeons in Group DS clearly responded more than those in Group OS', but the amount of variation resulted in a nonsignificant effect of Group. Responding to the retained *Xa-* was much lower for pigeons in Group OS, with one pigeon not responding at all on test trials of *Xa-*. Examining the difference score, one pigeon in Group DS responding strongly in the opposite direction of the other two pigeons on *Xa-* trials, while the two other pigeons in this group showed responding in the direction indicated by the original training of *Xa* despite responding in the opposite direction on *Wa-* trials (see Figure 10). This resulted in a mean difference score indicating responding predominantly to the right (in the opposite direction of original training), despite two of three pigeons responding predominately to the left. Due to this, any conclusions based on mean statistics should be viewed with caution for Exp. 1b.

General Discussion

The procedural differences between Ruprecht et al. (2014), Cleland et al. (2017) and the procedure of Exp. 1a likely resulted in Exp. 1a being a more difficult task. There were two main

differences between the current procedure and past spatial OS procedures 1) the addition of training with an unstable OS paired with an unstable LM and 2) the elimination of any nonreinforced LM alone trials (i.e., *a-* and *b-*). Due to one or both of these manipulations, the pigeons failed to demonstrate evidence of acquisition of all of the trained occasion setting trials types. In particular, *Xa* failed to acquire excitation, and *X* failed to controlling spatial responding relative to LM *a* at test. Although *Wb-*, *Wa-*, and *Yb-* all elicited excitation and spatial control, pigeons were unable to learn all four trial types to the same degree, becoming especially accurate on *Yb-* trials. It is possible that the difficulty of the task led them to learn about one trial type which happened to be the stable OS training trial *Yb-*. That they learned to respond so accurately to a stable OS trial over an unstable OS trial is logical as there is no spatial interference by *Y* being paired with reinforcement for responding in both directions. Less apparent is why learning was acquired to a higher degree on *Yb-* trials compared to *Xa-* trials. The same conditions existed on both trials of *Yb-* and *Xa-*.

Examining both the number of responses and spatial control individually for each bird, as well as collapsed across pigeons, suggests extremely strong excitation and strong spatial control on trials of *Yb-* relative to all of the other trained occasion setting trials. There was a complete lack of excitation and spatial control on trials of *Xa-*, and slightly more but still weak excitation and spatial control on trials of *Wa-* and *Wb-*. These results taken together indicate that pigeons were only able to perform with high accuracy on the trained OS trials that were paired with LM *b*. Based on excitatory transfer to *Xb-* we hypothesize that *b* was highly excitatory, and that there was likely transfer of excitation from *Wb-* to *Xb-*. Spatial control was likely the result of generalization from “*b not with Y*” to *Xb-*. By learning one configurations of stimuli (i.e., *Y* with *b*) and responding in the opposite direction to all other configurations with *b*, the pigeons were

able to respond highly accurately on *Yb*- trials and *Wb*- trials. This also explains transfer to *Xb*- trials despite no control of excitation or spatial responding to the previously trained OS trial *Xa*-.

Evidence of transfer in Exp. 1a was only found on transfer trials with a LM that had previously been a part of an OS (*Xb*-). Responding was lowest on transfer trials to a LM that were trained as an excitor and to a novel LM. These findings were consistent with the findings of Leising et al. (2015). Continuing with the hypothesis that the pigeons in Exp. 1a were solving the task by forming a configuration of *Yb*, this lack of transfer was likely due to generalization decrement as a result of the physical differences between the stimuli, but also due to the difference in the training history of LM *c* and *d*. Since these LMs had not previously been modulated by a OS, transfer was to a lesser degree than to the LM that had been trained as part of an OS pairing.

Unfortunately, because there was no evidence of acquisition of *Xa* in Exp. 1a it is difficult to examine the original question posed by Exp. 1b as to whether or not posttraining excitation of an OS will affect its ability to modulate a spatial response to a LM. Rescorla (1986) previously found no effect of posttraining excitation of the OS alone. We were unable to examine this in Group DS, as they had never learned the original *Xa* training. Any spatial retraining would not interfere with the original learning to *Xa*, as the pigeons never demonstrated acquisition on *Xa* trials at test.

However, it is worth examining these retraining effects on response and spatial control on *Xa*, as training data from Exp. 1a suggested that the pigeons had learned to respond accurately on trials of *Xa*, but that this learning was not expressed during test trials of *Xa*, perhaps because of the differences between the conditions during training and test. If the pigeons had acquired *Xa*, it appears that the retraining for both Group OS' and Group DS interfered with *X*'s ability to

control responding to *a*. In both groups, two of three pigeons showed poor spatial control, but in the direction trained during Exp. 1a. The other pigeon in each group showed either no responding, or responding in the opposite direction from what was trained during Exp. 1a. If this is reflective of disruption of control by *X*, it suggests that both OS training and DS training with *X* interfered with control by *X*. These results indicate that in this procedure retraining of an OS as a DS does interfere with its modulatory abilities, suggesting that the learning during OS training and learning during excitatory training are to some extent similar, and that learning during occasion setting training is not fully distinct from what is learned during excitatory training.

Some important limitations of the current set of experiments was the small number of subjects. Of the eight pigeons who began the experiment, only six advanced to testing and Exp. 1b. With such a small sample size and so much variation in responding, the averages are less valuable and therefore the statistics based on these averages should be interpreted with caution. Another consideration is the conditions of testing themselves. In Exp. 1a, pigeons received a block of 11 nonreinforced testing trials. Although counterbalancing of the order should have negated any order effects (*Xa-* was on average the 6th trial in the testing block, which was the same for the other test trials) it is possible that the large amount of testing trials in a block resulted in extinction and resulting in responding that differed from what was seen during training. Unlike the pigeons in Cleland et al. (2017), these pigeons were not exposed to nonreinforced trials of the LMs alone. This left them with little exposure to partial reinforcement, and therefore less resistant to the effects of extinction. As a result, these pigeons responded fewer times at test than during training.

These findings suggest that either the stability of the OS or the exclusion of nonreinforced LM alone trials affected how the OS training trials were learned and the degree to

which they were acquired. The results of Exp. 1a and 1b suggest that these training parameters result in learning that differs from typical learning within serial occasion setting procedures, in that acquisition of this task was much more difficult. Further research is needed to examine whether the exclusion of nonreinforced LM alone trials or the addition of an unstable OS resulted in poor control by some of the previously trained OS trial types at testing. One of these manipulations may have resulted in configural learning, explaining the lack of transfer of Y to a , despite Yb -controlling excitation and spatial responding.

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ABSTRACT

MANIPULATIONS OF THE SPATIAL STABILITY OF AN OCCASION SETTER ALTER SOME ASPECT OF BEHAVIOR DURING A LANDMARK-BASED SEARCH TASK

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An occasion setter (OS) is a stimulus that sets the occasion for responding to another stimulus. The current experiments examined the effect of spatial stability (Experiment 1a) and retraining of an OS (Experiment 1b) in a spatial occasion setting task in pigeons. An OS (i.e., a colored background) set the occasion for the location at which pecks were reinforced relative to a landmark (i.e., a colored square). In Experiment 1a, pigeons were trained with an OS that had an unstable spatial relationship with the goal. In Experiment 1b, an OS was retrained as a spatially unstable OS for another landmark or a spatially unstable discriminative stimulus. The pigeons failed to demonstrate evidence of acquisition of all of the OS trials in Experiment 1a, and retraining of the OS disrupted accuracy for both conditions in Experiment 1b. Spatial instability and/or a lack of nonreinforced landmark training disrupted performance.