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Effects of Age, Task Type, and Information Load on Discrimination Learning

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EFFECTS OF AGE, TASK TYPE, AND INFORMATION LOAD ON DISCRIMINATION LEARNING

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The feature positive effect (FPE) is a phenomenon in discrimination learning by which learning occurs more quickly when the presence (Feature positive; FP), rather than absence (Feature negative; FN) of a stimulus indicates a response should be made. Although the FPE has been extensively corroborated, a reversal, or feature negative effect (FNE), has been found when a target stimulus comes from a smaller set of stimuli (Fiedler, Eckert, & Poysiak, 1988). Age differences in FP and FN learning indicate that older adults perform more poorly than young adults on both FP and FN tasks, and are likely related to decline in working memory (WM) throughout adulthood (Mutter, Haggbloom, Plumlee, & Schrimer, 2006). This study used a successive discrimination task to compare young and older adults' performance across FP and FN conditions under low (three of a set of four stimuli were presented) and high (three of a set of six stimuli were presented) information load (IL). Results from rule articulation, final incorrect and 12 consecutive trials correct did not support the hypotheses, but trend analyses provided partial support. Under low IL, YA demonstrated a FN response bias whereas OA showed no bias. Under high IL, YA and OA demonstrated equivalent performance whether the target stimulus was present or absent in the FP condition. In the FN condition OA performed better when the target stimulus was absent while YA showed no bias. These

findings indicate FN task performance varies by age and this variation changes based on IL condition.

Introduction

Often a cue's absence, which could be valuable in solving a problem, is not noticed or is vastly underestimated in relation to a present cue. For example, when attempting to solve a crime, it might be more informative to notice the absence of fingerprints than their presence (Rusconi & McKenzie, 2013). It may also be more informative to notice the absence of specific symptoms when diagnosing a patient. For example, if diagnosing a child with difficulties in the social realm who exhibits characteristics similar to that of autism, it would be imperative to notice the absence of a delay in language development, as delayed language development is a major component of having autism (American Psychiatric Association, 2013). This tendency to not recognize the absence of something or to discount its importance in relation to what is present has been studied in learning tasks and is called the feature positive effect (FPE). The FPE is an aspect of discrimination learning, or learning to respond to stimuli differentially and can be described as the tendency to learn to respond more quickly to the presence of a stimulus than to the absence of a stimulus (Domjan, 2010; Fiedler, Eckert, & Polysiak, 1988). This introduction will discuss the FPE and relevant findings such as conditions in which it occurs, influences of age-related differences, and its occurrence across species, all of which provide the background and context for the proposed research.

Features of the Feature Positive Effect

The FPE is ubiquitous in that it has been discovered in a variety of species, including pigeons, rats, monkeys, and humans (Fazio, Sherman, & Herr, 1982; Lea, 1974; Mutter, Haggbloom, Plumlee, & Schrimer, 2006; Newman, Wolff, & Hearst, 1980;

Pace, McCoy, & Nallan, 1980; Reid, Rapport, & Le, 2013; Sainsbury, 1971a). Given that the FPE occurs across multiple species, it appears to be a natural form of learning and may have an evolutionary history. Specifically, it has been suggested that an organism monitoring events that are crucial for survival would focus more, if not entirely, on present occurrences rather than absent occurrences. This is because events crucial to survival are relatively sparse, meaning it would be much more efficient for an organism to pay attention to the presence instead of the absence of these events (Newman et al., 1980).

Stimuli to test the FPE can be either feature positive (FP), in which the presence of a relevant feature dictates a response should be made, or feature negative (FN), in which the absence of a relevant feature dictates that a response should be made (Mutter et al., 2006). To study the FPE, tasks must be designed that are appropriate to the type of sample being tested (e.g., children, adult humans, rats, etc.), and, despite the potential evolutionary history of the FPE, task types do not have to be related to aspects of survival; FP biases appear to be dominant in the learning of individuals. This will be important to remember when examining the majority of literature on this topic as well as considering the notion of the feature negative effect (FNE), the opposite of the FPE, in which discrimination learning occurs more quickly in response to the absence of a stimulus than the presence (Fiedler et al., 1988).

Discovery and Early Findings on the FPE

Nonhuman Studies. The FPE was first discovered in pigeons. Results of an early study with pigeons, using both a FP and FN task in a between-groups design, demonstrated that pigeons in the FP condition learned to discriminate successfully whereas those in the FN condition did not (Sainsbury, 1971a). Initially it was believed this clear asymmetry in discrimination learning between FP and FN stimuli was due to the physiology of pigeons, as they cannot properly see past their beaks to perceive the feature. However, the notion that the FPE is specific to pigeons was disconfirmed when rats were also shown to learn a FP task but fail to learn a FN task (Lea, 1974).

The FPE was later explored in greater depth in both rhesus monkeys and pigeons (Pace et al., 1980), and it was discovered that transfer effects between FN and FP training are possible. Both the monkeys and pigeons displayed facilitation in FN performance after being trained on a FP task, whereas initial training on a FN task led to attenuated performance on a subsequent FP task. Pace et al. hypothesized this finding was due to the animals learning the feature in the FP condition, responding appropriately, and then learning to inhibit responding to said feature when engaged in the FN task. However, in the FN to FP condition, the animals did not learn what the feature was and were therefore unable to respond to the feature appropriately when the FN task switched to an FP task (Pace et al., 1980). This suggests that the strength of the FPE can be modified by the order of tasks as FN learning can be facilitated. The facilitation of FN learning following FP learning has also been found in humans (Mutter et al, 2006; Nallan et al., 1981), suggesting that the FPE is not absolute-and is relative to the type of learning conditions employed.

Despite this seeming malleability of the FPE, it is nonetheless very pervasive. A study with pigeons made the present and absent predictors of a food reward equally probable by removing the interval between trials (Hearst & Wolff, 1989). The predictors become equally probable because the immediate presentation of a reward for a correct response removed the possibility of interference from the reward being associated with some other aspect of the stimuli or task when it was presented after a delay. The reward was signaled either by the occurrence of a light or tone or by the removal of a light or tone, and the pigeons had to peck an apparatus to make a response. The results indicated that although the predictability was equal, pigeons consistently made more correct responses when presence, the occurrence of the light or tone, rather than absence, the removal of light or tone, predicted reception of food. This was true in both between and within group manipulations across four experiments (Hearst & Wolff, 1989).

Human Studies. In line with the evidence on the pervasiveness of the FPE, one study using a sample of adult humans demonstrated the wide range of stimuli and instructions under which the FPE is observed. For example, the FPE was found to occur in a series of experiments in which feedback was either immediate or delayed, when discriminations were completed simultaneously or successively, and when the number of features and types of features were changed (e.g., presenting a larger number of irrelevant features, using letters vs. shapes as features), demonstrating that the FPE is not constrained to a specific type of task (Newman et al., 1980).

Being explicitly informed about some aspect of the stimuli can attenuate the FPE. When participants were directly told there was something in the task that made the stimuli “not good”, the FN participants performed just as well as the FP participants. Further, when participants were told something was “good” about the stimuli, the FP participants performed better than FN participants, producing the FPE (Newman et al., 1980). This finding indicates that the type of instructions given to participants can influence the FPE, which suggests the FPE might be a default setting in relation to discrimination that can be manipulated. Explicit task instructions informing participants that the absence of something in the task is relevant to completing it successfully led to greater FN performance relative to FP performance. In addition, humans have shown more accurate FN task performance if they are trained on an FP task first, implicating the order of tasks in the occurrence and relative strength of the FPE (Mutter et al, 2006; Nallan et al., 1980). It is apparent that despite the FPE's appearance as an innate characteristic of discrimination learning across a variety of species, it can be manipulated in ways that reduce its occurrence. Perhaps the FPE operates as a default in natural scenarios only when specific conditions are met, such as when instructions are not given to alert individuals to attend to the absence of something, which is often the case in discrimination learning tasks as participants are typically informed only that they are to attempt to learn the rule or system that makes the stimuli correct or incorrect; they are not specifically told to attend to what is absent when they are learning an FN discrimination. These findings warrant further research.

The FPE has not only been found in traditional discrimination learning tasks but also in novel tasks such as one that involved rating how humorous cartoons were using different response methods (e.g., rating funniness by pressing a button or rating funniness by not pressing a button). Ratings of funny and not funny were each higher when paired with a response than when paired with no response (Fazio et al., 1982). Although this task examines the FPE as a function of the responses rather than the cues, similar biases toward present versus absent information were found. These findings demonstrate a FP bias in how individuals respond, which expands previous research indicating a bias toward learning faster from present versus absent cues. This suggests that just like with discrimination learning, which occurs more quickly when the goal is to learn what is present, it is easier to learn when making a response than when making no response. In other words, the subjective perceptions of a cartoon as humorous were altered by the rating of humorousness being expressed by either performing or inhibiting a response. Perception and how that perception is expressed is therefore intertwined and appears to be dependent on the presence and absence of stimuli and response types, with a bias toward present stimuli and/or responses. This illustrates the pervasiveness of the FPE outside of traditional learning paradigms (Cherubini et al., 2013).

Recent Examinations of the FPE

Studies on the FPE within the past ten years have yielded findings replicating prior research as well as novel findings. These studies show that FP biases are also present when the task involves either stimuli with alternating positions or when stimuli serve to signal where a target will be located. Replication of previous findings in humans continue to show that FP discriminations are learned much more quickly than FN discriminations (Lotz, Ungoer, Koenig, Pearce, & Lachnit, 2012). Specifically, participants were instructed to determine when a green circle would appear on the computer screen, and that they should base their predictions on the presentation of a letter or pair of letters that are presented on the screen prior to the circle's appearance. In the FP condition, a pair of letters predicted the circle's appearance while a single letter did not. In the FN condition, the single letter predicted the circle's appearance while the pair of letters did not. In other words, for FP discrimination, the presence of an additional letter predicted the circle's appearance while the absence of the second letter did not, and vice versa for the FN condition. Participants learned to respond to the presence of a second letter faster than to the absence of a second letter. Studies have also found a FP bias in spatial tasks that require learning to predict when to respond to specific spatial locations correctly, further expanding the knowledge of conditions in which an FPE can occur in both rats and humans. In a study by Reid et al., (2013), rats were presented with either a lightbulb turned on or off to indicate responses, and regardless of whether the bulbs were located in the front or rear of the box they were in, the rats learned to respond more quickly to the lightbulb turned on than the one that was dark. Ruprecht, Wolf, Quintana, & Leising, (2014) found that humans completed a more complex task in which they had to determine where a target would appear on a screen based on a spatial cue only if the spatial cue was preceded by a colored background on the screen. Specifically, participants demonstrated a bias toward correctly determining the target's location when the target was preceded by both the colored background and spatial cue rather than the spatial cue alone.

The Role of Explicit Probability Knowledge. Knowledge of the probability of a stimulus occurring can have an influence on subsequent FP/FN performance in humans in accordance with other factors such as type of feature and ratio of present to absent cues (Cherubini et al., 2013; Rusconi, Crippa, Russo, & Cherubini, 2012). In a task in which participants determined whether a card with a pattern of letters printed on it was drawn from one deck or a second deck, choices were consistently made based on present cues (i.e., if a card with the letter "A" was correctly chosen as belonging to deck one, then subsequent cards that include the letter "A" were also likely to be chosen as belonging to deck one) more than they were made based on absent cues (i.e., if a card without the letter "A" was correctly determined to belong to deck one, subsequent cards with an absence of “A” were not more likely to be determined to belong to deck one). This was true when participants were only informed of the probabilities of nonoccurrence of stimuli, when they were informed of occurrences only, or when they were informed of both nonoccurrences and occurrences. Even with explicit knowledge about the probability of the occurrence of a stimulus, participants fail to differentially respond to stimuli in a way that would improve performance. What did appear to influence the FPE, however, was the ratio of present to absent cues. Specifically, the FPE diminished somewhat when the present:absent ratio was 3:2 and probabilities of occurrences were shared with participants, although this effect did not persist with present:absent ratios of 2:3 or 2:2 or when participants were informed about both occurrences and nonoccurrences or informed of only nonoccurrences (Cherubini et al., 2013).

Another study by Rusconi and colleagues (2012) also found that a ratio of present to absent cues of 2:1 diminished the occurrence of a FP bias, as opposed to equal present to absent cue ratios which did not diminish the FP bias, and this happened in conjunction with participants being explicitly informed about the probability of the occurrence of a stimulus. However, this effect only occurred when the cue’s presence did not determine a response should be made, meaning when the presence of the cue did require a response, the FP bias remained strong. This suggests that probability knowledge alone is not enough to alter the typical pattern of FP/FN performance but this variable in combination with a manipulation of the ratio of present:absent cues may help play a role in attenuating the FPE. This finding supports the notion that the FPE is fundamentally a default setting as task manipulations can attenuate the FP bias. Studies have also indicated that specific manipulations of predictive values alone do not significantly alter the FPE, but the FPE is diminished when predictive values are manipulated in conjunction with explicit knowledge of the ratio of present:absent cues (Cherubini, Rusconi, Russo, & Crippa, 2013). This is a more complex manipulation than that applied by Hearst and Wolff (1989). Humans are able to perform a more diverse set of FPE tasks by being able to employ instructions in a more complex manner than pigeons. This could mean the FP bias, or attenuation of this bias, is somewhat dependent upon being explicitly told about probability (e.g., “It is more likely stimulus A will occur during trial X versus trial Y“).

A separate study of probability knowledge and the FPE using the same deck drawing task as described above (Cherubini et al., 2013) also found that probability knowledge alone does not alter the FPE’s pervasiveness in the participant’s responses (Rusconi et al., 2012). However, like the aforementioned study, when combined with another factor, the FPE was attenuated. In this case, the use of substitutive versus nonsubstitutive features played the crucial role. Substitutive features are those whose absence necessitates the presence of some other feature (i.e., if the color red is absent from a table, some other color must be present), whereas nonsubstitutive features are those whose absence do not necessitate the presence of another (i.e., the absence of the letter X on a square does not require a different letter be present on the square as the square can be devoid of any other features). Substitutive features, in combination with explicit knowledge of stimulus occurrence probability, but not alone, led to a diminished FPE. In other words, the FPE is attenuated when the features necessitate a replacement feature if absent and participants are told the likelihood that the stimulus of interest is going to occur. The crucial insight gleaned from the failure of substitutive features alone to decrease the frequency of an FPE is that the effect is not merely due to an inability to successfully think about absent information. This is because substitutive features circumvent the problem of absence as feature absence leads to a necessary feature presence. Ultimately these findings indicate that being able to assess absent features through present features does not necessarily aid in attenuating the FPE, given that substitutive features must be combined with explicit probability knowledge about the occurrence of a stimulus in order to weaken the FP discrimination bias. For example, if the participant is told the probability that a red circle will appear, with red being the substitutive feature, and a red triangle, red square, and green circle appear, the red is absent and replaced with green. It is easier for the participant to note the absence of the red circle when the red is replaced with green (Beckmann & Young, 2007; Rusconi et al., 2012).

The Feature Negative Effect. A few studies have demonstrated a reversal of the FPE or an FNE, in which FN discrimination occurs more quickly than FP discrimination. The FNE may be related to individuals transforming a feature negative rule into a feature positive rule. In an unusual discrimination learning task in which participants determined whether applause would follow the presentation of a short movie, Beckmann & Young (2007) presented participants with one of two conditions. In the constant condition, two movies, A and B, were repeated and varying movies (movie V), were introduced that never repeated, with the presence (FP condition) or absence (FN condition) of movie A being the intended feature to determine that applause would follow. In the varied condition, movie A remained constant but all other movies were novel and never repeated, with the presence or absence of movie A being the rule like in the constant condition. FN learning rather than FP learning occurred more quickly in the constant condition while FP learning occurred more quickly in the varied condition. These findings suggest that participants framed the rule for the constant condition in terms of an FP novelty task rather than an FN task. In other words, novelty itself served as a feature in the task as novel movie V, which was a previously unseen movie each time one was presented, predicted a response rather than the absence of constant movie A.

Fiedler and his colleagues (Fiedler et al., 1988) also examined conditions under which an FNE rather than an FPE would occur in a series of six experiments involving adult human participants. Participants completed several variants of FP and FN discriminations, involving types of feedback and number of symbols, and were instructed to inform the researcher what they thought the rule was. FN learning was found to occur more quickly than FP learning when both FP and FN learning involved noncontingent feedback, meaning participants were informed if they were right or wrong regardless of the response made. FP learning occurred more quickly than FN learning when both FP and FN learning involved contingent feedback, meaning feedback was only given when participants were correct. In addition, when four instead of six symbols were used in the learning task, a FNE was observed rather than a FPE. In both the four and six symbol conditions, participants were exposed to a subset of three symbols with a blank space allocated randomly between them. The four symbol condition consisted of displays of subsets of three of the four total symbols (square, triangle, cross, circle) in random order while the six symbol condition consisted of displays of subsets of three of the six total symbols (square, triangle, cross, circle, tilted Z, X with bars on top and bottom) in random order. One of the symbols was designated as the target feature, and a display was correct when it contained that feature and incorrect when it did not in the FP condition. In the FN condition a display was incorrect when it contained the target feature and correct when it did not. Participants would choose whether they thought a presented display was correct or incorrect. The FNE was hypothesized to be due to the greater invariance present in the four symbol condition, given that there are fewer combinations of randomly ordered displays that could be created, and this helped participants learn more quickly to respond when a target feature was absent, leading to a greater number of correct responses in the FN, four symbol condition than was found in the FN, six symbol condition. However, when Fiedler et al. asked participants what they believed the rule was for the FN task, they responded not by describing the absence of the feature but by describing the repeated presence of certain stimulus elements, such as stating that the presence of the circle, square, and cross made the displays correct instead of stating that the absence of the triangle (the actual FN rule) made them correct.

The Fiedler et al. (1988) findings show that feedback contingency and the number of stimulus elements used in a task can alter whether an FNE or FPE occurs. More importantly, they suggest that invariant patterns may have been helping participants determine how to respond correctly in the FN condition, and four stimuli allow for more constancy than six (Fiedler et al., 1989). Specifically, the number of patterns possible with four stimuli is less than that for six stimuli, and if participants made feature negative judgments in terms of feature positive rules, it would be faster to learn the consistencies, and therefore invariances, in a set of four randomly ordered versus six randomly ordered stimuli. Thus the FPE seems to be influenced by number of stimuli, contingency of feedback, knowledge of probability, type of feature used (i.e., substitutive versus nonsubstitutive), as well as present:absent cue ratios

Theoretical Explanations for the FPE. Theories of associative and inductive reasoning suggest that differences in cognitive abilities could also play a role in the FPE. When engaged in a FP/FN task, the participant creates associations between the stimuli and outcome (Jenkins & Sainsbury, 1970). For example, when learning a FP discrimination that the presence of a square is the target feature, the square predicts the outcome 100% of the time, making it more predictive than the other stimuli. However, when learning a FN discrimination that the absence of a square is the target feature, the predictive value of the square is zero, meaning that its presence serves no role in predicting a correct response. Meanwhile, the irrelevant background stimuli have a predictive value of 50% (Mutter et al., 2006). Therefore, FN discriminations are more difficult because the irrelevant background features' predictive value of only 50% and the target feature's zero predictive value add a much higher degree of uncertainty in determining when to respond than an FP discrimination whose target feature provides certainty with a predictive value of 100%.

From the viewpoint of inductive reasoning theory, participants create hypotheses about the stimuli and assess their validity following feedback as to whether or not their response choice was correct (Hearst, 1991; Levine 1966; Mutter et al., 2006). For example, during FP discrimination, when participants make a correct response, they reduce the number of competing hypotheses. If correctly responding to a two symbol subset of a circle, cross, triangle, and square where the square and triangle are present, then either the triangle or square is the target feature. If the next subset is the square and cross and responding leads to feedback that the response is incorrect, it can be determined that the hypothesis "the square is the target feature" is incorrect and "the triangle is the target feature" is correct. FN discriminations are much more complex. If the absence of the triangle is the target feature, and a response is correct for a display of a square and cross, the hypotheses may be drawn that either "the square is the target feature" or "the cross is the target feature". However, when faced with displays of a triangle and cross and then triangle and square, participants will be told they are incorrect when responding to both. Therefore, participants create hypotheses that are actually taking them further away from the correct rule, as they tend to create rules based on the presence of features, and given this, there are many more possibilities as to what the rule may be in FN discriminations (Mutter et al, 2006).

Age and Working Memory. If FN discriminations require more items to be considered in both an associative and inductive manner than FP discriminations, then working memory capacity (WM; memory used to process current information) may play a role in the greater difficulty of FN discrimination. Research has indicated that younger and older adults show marked differences in working memory (WM) that may affect their inductive reasoning and learning (Belleville, Rouleau, & Caza, 1998; Foos, 1989; Fristoe, Salthouse, & Woodard, 1997; Hartman, Bolton, & Fehnel, 2001; Jain & Kar, 2014; Oberauer, Wendland, & Kliegl, 2003; Rodriguez-Villagra, Gothe, Oberauer, & Kliegl, 2013; Salthouse & Babcock, 1991; Salthouse, Babcock, & Shaw, 1991;). The Wisconsin Card Sorting Task (WCST) is an inductive reasoning task that requires participants to sort cards by form, number, or color based on a rule that they must learn through only positive or negative feedback from the researcher. After the rule is learned and items are correctly sorted for ten trials the rule is changed. The participant is not told about this rule change and must then adapt and attempt to learn the new rule (Fristoe et al., 1997). Older adults' inductive reasoning on this task has been shown to be impaired (Rhodes, 2004). Moreover, Hartman et al. (2001) found that older adults (mean age 70) continued to make more errors than younger adults (mean age 20) even when WM demands, such as storage and processing requirements, were minimized. This suggests that a decline in the ability to update information in WM may be responsible for the discrepancy in performance between older and younger adults. An inability to successfully update information in WM (e.g., continuing to make the same response despite rule changes in the WCST) may be indicative of a smaller WM capacity.

Using the alphabetical span procedure in which participants must remember a list of words in alphabetical order, Belleville et al. (1998) found no age differences in performance between younger and older adults when list length was controlled based on individual differences in WM capacity. Additionally, when performing arithmetic tasks, younger and older adults perform similarly except when WM demands were increased. This increase led to a decrease in arithmetic performance in older adults that was not present for younger adults (Oberauer et al., 2003).

Age, WM and the FPE. Given that associative learning and inductive reasoning in FN discrimination place greater demands on WM than these processes in FP discrimination, it is reasonable to suspect that the FPE may manifest differently in younger versus older adults. Little research has investigated age and the FPE. Results of a FP/FN discrimination task with children revealed that five year old children displayed a FPE, seven year old children displayed an attenuated FPE, and nine year old children did not display a FPE at all (Sainsbury, 1971b). These results are indicative of a change in discrimination learning abilities with age. All of the children received displays with three of four stimuli, and the nine year old children performed similarly to the adults who received four stimuli in the study by Fiedler et al. (1988). These findings suggest that a certain degree of informational complexity is necessary to elicit an FP bias in discrimination learning tasks for older children and adults.

Older adults have a more difficult time than younger adults in FN versus FP learning (Mutter et al., 2006; Mutter & Pliske, 1996). Specifically, in a study of younger adults with an average age of approximately 21 and older adults with an average age of approximately 72, results showed that FP and FN learning occurred more quickly in younger rather than older adults, as younger adults articulated the FP or FN rule after fewer trials than older adults. An additional manipulation in this study involved loading WM of some of the younger adults, by having them complete the task while also rehearsing unique seven digit strings prior to the start of every trial, to observe their subsequent discrimination learning performance. This manipulation was performed because older adults exhibit impairments in inductive reasoning that are associated with a decline in WM capacity, such that the ability to store information and continuously update that information is impaired. Therefore it was hypothesized that inductive reasoning in discrimination learning would also be impaired for younger adults with loaded WM if the deficit for older adults is due to WM capacity decline. The hypothesis was supported by the results, which indicated that younger adults with WM loaded, like older adults, learned FP and FN discriminations more slowly than younger adults without loaded WM. Despite this, both the WM loaded younger adults and older adults failed to demonstrate a greater FPE bias than the younger adults, which pointed to a more general discrimination learning deficit rather than a specific FPE deficit (Mutter et al., 2006).

Additionally, FN discrimination learning can be facilitated by previous FP discrimination learning (Nallan et al., 1980; Pace et al., 1980). Mutter et al. (2006) also demonstrated this, in that younger adults' FN learning was facilitated by prior FP learning, whereas older adults and WM loaded younger adults did not display this effect. However, older adults and WM loaded younger adults were able to learn a subsequent FP task after prior FP learning, suggesting that a WM deficit is related to difficulty in learning predictors based on absent rather than present information.

Summary and Present Study

In sum, the FPE is pervasive across species, has an evolutionary background potentially related to survival (despite the effect occurring in tasks not directly related to survival), and can be demonstrated in diverse task types and situations. Differences in FP and FN learning are seen throughout the lifespan, and these differences may be at least partially explained by reduced WM capacities in very young children and older adults (Mutter et al., 2006; Sainsbury, 1971b). In addition, a FNE can be elicited instead of the FPE when information load is low, as is the case when three out of four symbols are presented versus three out of six symbols (Fiedler et al., 1988). Information load may be another variable that influences age differences in FP and FN discrimination. This is because greater information loads place greater demands on WM and older adults' performance is generally worse with greater WM loads (Oberauer et al., 2003), as was demonstrated when comparing older and young adults' performance on arithmetic problems while simultaneously loading WM. It thus seems reasonable to hypothesize that FP and FN discrimination learning could vary with age in conjunction with information load or the number of stimulus elements. Therefore, in the present study, younger and older adults were presented with FP/FN discrimination tasks involving either a four or six symbol stimulus set.

A low information load (i.e., four symbol stimulus set) was expected to result in a reversal of the FPE for younger adults meaning that younger adults will learn FN discriminations faster than FP discriminations (cf., Fiedler et al., 1988). However, a high information load (i.e., six symbol stimulus set) should elicit the typical FPE. The level of the information load may also influence the FP and FN discrimination performance of older adults in that their discrimination learning for both FP and FN will be better in the low load condition than in the high load condition. However, they may not show a FNE in the low information load condition. In other words, regardless of information load they may exhibit faster learning for FP than FN discrimination.

The specific hypotheses for this experiment are as follows:

1. Consistent with Mutter et al. (2006), older adults should take a greater number of trials to articulate an appropriate rule and to reach a criterion of twelve trials correct in a row than young adults regardless of discrimination type (FP vs. FN) or information load (four vs. six symbol).

2. In line with Fiedler et al. (1988), both young and older adults should articulate an appropriate rule after fewer trials and reach their last incorrect trial after fewer trials in the four symbol condition than in the six symbol condition for both FP and FN learning.

3. Young adults should show an FNE when information load is low but not when information load is high. Young adults should articulate an acceptable rule and reach their last incorrect trial after fewer trials in FN versus FP discrimination in the four

symbol condition but should articulate an acceptable rule and reach their last incorrect trial after fewer trials in FP versus FN discrimination in the six symbol condition.

4. Older adults, unlike young adults will not show a FNE in the low information load condition. Older adults should articulate an acceptable rule and reach their last incorrect trial after fewer trials in FP versus FN discrimination for both the four and six symbol conditions.

Methods

Participants

Ninety-seven participants completed the study. Forty-eight younger adults (*M*age= 19.33, *SD* = 1.39) were recruited from Western Kentucky University's Study Board and compensated with one study board credit toward a psychology or psychological science course per 15 minutes of participation. The majority of participants were female (79.2%) and white (62.5%) or African American (18.8%), followed by Asian-Pacific Islander (8.3%), mixed race (6.2%), Hispanic (2.1%), or Middle Eastern (2.1%). Most participants also reported being of middle (47.9%) or upper-middle (29.2%) class, followed by lower-middle (10.4%), lower (4.2%), lower-upper class (2.1%), or upper-lower class (2.1%). Forty-nine older adults (*M*age = 68.35, *SD* = 5.08) were recruited from volunteer databases in labs of the department of psychological sciences, e-mails sent to Western Kentucky University faculty and staff, and referrals from older adults who had completed a past or the current study. Each older adult was screened using the Telephone Mini Mental State Examination to ensure they were in good cognitive health prior to scheduling for the study. Participants were 53.1% female and

98% white, with one participant choosing not to disclose race. Like younger adults, the majority of older adults reported being either middle class (55.1%) or upper-middle class (26.5%), followed by lower-middle class (10.2%), lower-upper class (4.1%), lower-middle class (2.0%), or lower class (2.0%). Each participant was compensated with $10.00 per hour of participant with a grant provided by Western Kentucky University.

Materials

Research Design. A quasi-experimental 2 (group: younger vs. older) X 2 (information load: four symbols vs. six symbols) X 2 (discrimination type: FP vs. FN) between subjects factorial design was used to examine the effects of group, discrimination conditions, and number of symbols on discrimination performance. Group is the quasi variable in this design as age cannot be manipulated. Twelve young and 12 older participants were randomly assigned to each of the four possible combinations of information load and discrimination type: four symbols and FP, six symbols and FP, four symbols and FN, and six symbols and FN, with one additional older adult assigned to the FP four symbol condition. In addition, each participant was randomly assigned to receive either the triangle, square, circle, or cross as the target feature. The effects of these variables on three measures of discrimination performance were investigated: (1) the number of the trial in which the participant articulates the correct rule, otherwise referred to as the strict rule (2) the number of the trial in which the participant articulates a rule that is not the strict rule but will lead to the correct response, otherwise referred to as the lenient rule, (3) the number of the participant's last incorrect trial, and (4) the number in which a participant reached a run of 12 consecutive trials correct. Additionally, the effect of block (1-12 in the six symbol condition and 1-18 in the four symbol condition) and task type (FP or FN) on mean number of trials correct when the target feature was present or absent was investigated.

Individual Difference Measures. All participants completed the digit symbol task (Wechsler, 1997), reading span (Daneman & Carpenter, 1980), and Advanced vocabulary (Ekstrom, French, Harman, & Dermen, 1976) measures. Both the digit symbol, a measure of perceptual speed and incidental learning, and the Advanced Vocabulary scale, a measure of verbal knowledge, were administered in a pencil and paper format, and the reading span task, a measure of WM, was administered by iMac. These measures are necessary to assess individual differences in perceptual speed, WM, and verbal knowledge and were examined to determine that participants represented their respective populations (i.e., older adults should outperform younger adults on Advanced Vocabulary but younger adults should outperform older adults on reading span and digit symbol).

Experimental Stimuli. The experimental task was presented on an iMac monitor programmed with Superlab software. The four symbol condition consisted of a triangle, circle, square, and cross. There were a total of 108 trials, consisting of 18 blocks with six trials in each block. The blocks contained three correct and three incorrect displays, and the order of presentation was randomized with the constraint that participants were not exposed to more than two correct or incorrect displays in a row. Each stimulus display consisted of three symbols in randomized order. In all conditions, the target feature was either the triangle, square, circle, or cross. In the FP condition, the stimulus display containing the target feature is "correct" while the display without the target feature is "incorrect." In the FN condition, the display without the target feature is "correct" while the display containing the target feature is "incorrect."

The six symbol condition consisted of a triangle, circle, square, cross, X-barred, and diamond. There was a total of 240 trials, consisting of 12 blocks with 20 trials in each block. The blocks contained ten correct and ten incorrect stimulus displays, and the order of presentation was randomized with the constraint that participants were not exposed to more than two correct or incorrect displays in a row. Each stimulus display consisted of a set of three symbols in randomized order. Consistent with the four symbol condition, the target feature was either the triangle, square, circle, or cross. In the FP condition, the stimulus display containing the target feature is "correct" while the display without the target feature is "incorrect." In the FN condition, the display without the target feature is "correct" while the display containing the target feature is "incorrect." Appendix A provides an example of the presentation of task stimuli.

For both the four and six symbol conditions, each stimulus display remained on the screen for five seconds or until the participant made a response. If no response was made within five seconds, that trial was recorded as an error. Responses were indicated by pressing the "A" key labelled "Yes" and the "L" key labelled "No". A feedback screen then appeared informing the participant "That is correct" or "That is incorrect." This display remained on the screen for 1,000ms, at which point a screen saying "Rule?" appeared, allowing the participant the option to report a rule before the next trial was initiated by the experimenter with a mouse click.

Procedure

Participants completed an informed consent form and the biological and health questionnaire, followed by the experimental task. All participants were instructed to complete all trials in the both the four and six symbol conditions but to tell the researcher if they think they have determined the rule. Participants viewed the stimulus displays and press the “A” key if they believed the stimulus display was correct and press the “L” key” if they believed the stimulus display was not correct. Each stimulus display remained on the screen for five seconds or until a participant made a response. After making a response, a display saying “That is correct” or “That is incorrect” appeared for one second followed by a rule screen allowing the participant the option to report a rule before the next trial was initiated by the researcher with a mouse click. The number of trials taken to report a rule, regardless of whether the rule is correct or incorrect, was recorded on a document by the researcher that contains a list of all trials. The research also recorded what the participant said verbatim. This document allowed the researcher to track the number of trials completed prior to reporting a rule to include in data analysis. The researcher did not tell participants if they were correct or incorrect. Following the experimental task, participants completed the individual difference measures. One younger adult was excluded from the digit symbol analyses due to failure to follow instructions and one older adult was excluded from the reading span analyses due to the iMac not presenting the task properly. A summary of these results from a univariate ANOVA are provided in table 1 and reveal that older adults performed significantly better on the Advanced Vocabulary test than younger adults, $F(1, 95) = 94.27$, $p = .00$, $\eta^2_p = .50$, indicating older adults have a greater verbal knowledge. Younger adults performed significantly better than older adults on the reading span task, $F(1, 95) = 7.39$,

p = .01, η^2_p= .07, indicating younger adults have greater working memory capacity. Younger adults also performed significantly better than older adults on both the substitution, $F(1, 95) = 42.92$, p = .00, η^2_p= .31, and incidental learning, $F(1, 95) = 20.29$, p = .00, η^2_p= .18, portions of the digit symbol task, showing younger adults have greater processing speed and higher incidental learning scores. Finally, all participants were debriefed, thanked for their participation, and compensated for their time. Younger adults received Study Board credit and older adults received a check.

Table 1

Mean (Standard Deviation) Scores on Individual Differences Measures

Measure	Younger	Older
Reading Span*	2.58 (.99)	2.02 (1.04)
Advanced Vocabulary*	8.80 (3.92)	19.63 (6.65)
Digit Symbol Substitution*	80.06 (14.51)	61.80 (12.79)
Digit Symbol Incidental Learning*	24.06 (4.89)	18.84 (6.35)

Note. *p <. 01

Results

Data were scored for the dependent measures of articulation of a strict rule, lenient rule, last incorrect trial, and run of 12 trials correct as follows. Strict rule articulation was scored as whatever trial the participant articulated the actual rule. For example, if the task is four symbols and FP with the circle as the target feature, the rule is "displays containing the circle are correct." If the task if four symbol and FN with the circle as the target feature, the rule is "displays not containing the circle are correct." For participants to receive a strict rule score during articulation, they must therefore specifically identify the presence or absence of the target feature. Lenient rule articulation was scored as whatever trial the participant articulated a rule that would always lead to the correct response, whether it was the strict rule or not. For example, if the task is four symbols and the circle is the target feature and the participant stated “a display is correct when the triangle, square, and cross are present,” that rule was coded as lenient because it would always lead to the correct response despite it not being the strict rule. If participants articulated a strict rule, they were scored at that trial for both the strict and lenient rule (i.e., if the strict rule was articulated at trial 40, the score for strict and lenient was recorded at trial 40). If participants articulated a lenient rule but not a strict rule, they were given the corresponding score of 108 (four symbol) or 240 (six symbol) for the strict rule and their lenient rule score would be designated as the trial they articulated the lenient rule (i.e., if the lenient rule is articulated at trial 40, the participant receives a score of 40 for lenient rule). If participants did not articulate a rule, they were given a score of 108 in the four symbol condition and a score of 240 in the six symbol condition for both the strict and lenient rules. The last incorrect trial was scored as whichever trial participants responded to incorrectly that was followed by only correct responses. If participants got the final trial incorrect, their score was 108 or 240 depending on information load condition. Finally, the run of 12 was scored as the 12th consecutive correct trial. If this never occurred, participants were given a score of 108 or 240 depending on information load condition. Descriptive statistics for the strict and lenient rules, last incorrect trial, and run of 12 trials correct are shown in Table 2. An alpha of $p \leq .05$ was considered statistically significant for all analyses.

Discrimination Performance

Trials to articulation for both strict and lenient rules, the final incorrect trial, and run of 12 trials correct scores for both the low and high information load conditions were submitted to separate 2 (group: young vs. old) X 2 (discrimination type: FP vs. FN) between-subjects factorial ANOVAs. Information load was not included as a factor due to the fact that many participants received scores of 108 or 240 on the primary dependent measures for the low and high information load condition, respectively. The large difference between 108 and 240 would have resulted in a spurious effect of information load.

Low Information Load. The results for the low information load condition for each dependent variable were as follows. Older adults did not significantly differ from younger adults in the number of trials taken to articulate the strict rule, $F(1, 47) = 1.22$, $p = .28$, $\eta^2_p = .03$. There was also no main effect of task type (FP vs. FN) for trials to articulate the strict rule, $F(1, 47) = .26$, $p = .62$, $\eta^2_p = .01$, showing that participants in the FP condition did not articulate the strict rule sooner than those in the FN condition. Finally, the group by task type interaction was non-significant, $F(1, 47) = .57$, $p = .46$, $\eta^2_p = .01$, showing that number of trials to articulate a strict rule did not vary by levels of group or task type.

Older adults also did not significantly differ from younger adults in the number of trials take to articulate a lenient rule, $F(1, 47) = 1.73$, $p = .20$, $\eta^2_p = .04$. There was no main effect of task type for trials taken to articulate a lenient rule, $F(1, 47) = 3.86$, $p = .05$, $\eta^2_p = .04$, indicating that participants did not significantly differ in when they articulated the lenient rule in the FP or FN condition. The group by task type interaction was non-significant, $F(1, 47) = .13$, $p = .72$, $\eta^2_p = .00$, showing that number of trials to articulate a lenient rule did not vary by levels of group or task type.

Older adults did not significantly differ from younger adults on their last incorrect trial, $F(1, 47) = 2.10$, $p = .15$, $\eta^2_p = .05$. There was also no main effect of task type for last incorrect trial, $F(1, 47) = .95$, $p = .34$, $\eta^2_p = .02$, indicating that participants did not significantly differ in when they reached their last incorrect trial in the FP or FN condition. The group by task type interaction was non-significant, $F(1, 47) = .01$, $p = .93$, $\eta^2_p = .00$, which showed that number of trials to reach the last incorrect trial did not vary by levels of group or task type.

Finally, older adults did not significantly differ from younger adults on trials taken to reach a run of 12 correct, $F(1, 47) = .1.75$, $p = .19$, $\eta^2_p = .04$. There was also no main effect of task type on trials taken to each a run of 12 correct, $F(1, 47) = 1.82$, $p = .18$, $\eta^2_p = .04$, showing that participants did not significantly differ in when they reached a run of 12 trials correct in the FP or FN condition. The group by task type interaction was non-significant, $F(1, 47) = .97$, $p = .33$, $\eta^2_p = .02$, indicating that number of trials to reach a run of 12 trials correct did not vary by levels of group or task type.

High Information Load. The results for the high information load condition for each dependent variable were as follows. Older adults did not significantly differ from younger adults in the number of trials taken to articulate the strict rule, $F(1, 48) = .21$, $p = .65$, $\eta^2_p = .01$. There was also no main effect of task type (FP vs. FN) for trials to articulate the strict rule, $F(1, 48) = 1.33$, $p = .26$, $\eta^2_p = .03$, showing that participants did not significantly differ in when articulated the strict rule in the FP or FN condition. Finally, the group by task type interaction was non-significant, $F(1, 48) = .03$, $p = .86$, $\eta^2_p = .00$, indicating that number of trials to articulate a strict rule did not vary by levels of group or task type.

Older adults also did not significantly differ from younger adults in the number of trials taken to articulate a lenient rule, $F(1, 48) = .67$, $p = .42$, $\eta^2_p = .02$. There was no main effect of task type for trials taken to articulate a lenient rule, $F(1, 48) = 2.25$, $p = .14$, $\eta^2_p = .05$, showing that participants did not significantly differ in when they articulated the lenient rule in the FP or FN condition. The group by task type interaction was non-significant, $F(1, 48) = .29$, $p = .59$, $\eta^2_p = .01$, indicating that number of trials to articulate a lenient rule did not vary by levels of group or task type.

Older adults did not significantly differ from younger adults on their last incorrect trial, $F(1, 48) = .21$, $p = .65$, $\eta^2_p = .01$. There was also no main effect of task type for last incorrect trial, $F(1, 48) = 2.27$, $p = .14$, $\eta^2_p = .05$, showing that participants did not significantly differ in when they reached their last incorrect trial in the FP or FN condition. The group by task type interaction was non-significant, $F(1, 48) = .01$, $p = .92$, $\eta^2_p = .00$, which indicated that number of trials to reach the last incorrect trial did not vary by levels of group or task type.

Finally, older adults did not significantly differ from younger adults on trials taken to reach a run of 12 correct, $F(1, 48) = .24$, $p = .63$, $\eta^2_p = .01$. There was also no main effect of task type on trials taken to each a run of 12 correct, $F(1, 48) = 1.24$, $p = .27$, $\eta^2_p = .03$, showing that participants did not significantly differ in when they reached a run of 12 trials correct in the FP or FN condition. The group by task type interaction was non-significant, $F(1, 48) = .03$, $p = .85$, $\eta^2_p = .00$, which indicated that number of trials to reach a run of 12 trials correct did not vary by levels of group or task type.

Table 2
Mean (Standard Deviation) Performance on Experimental Task

Condition	SR	LR	LIC	R12
YA-FP				
LowIL	87.42(37.79)	87.42(37.79)	89.08(36.11)	89.33(34.50)
HighIL	198.75(76.10)	198.75(76.10)	218.17(47.00)	183.17(82.79)
OA-FP				
LowIL	103.75(14.72)	103.75(14.72)	100.08(15.93)	92.50(28.91)
HighIL	205.38(67.91)	205.38(67.91)	211.54(51.03)	190.77(74.87)
YA-FN				
LowIL	89.58(34.10)	75.91(40.51)	80.58(33.61)	67.33(36.97)
HighIL	168.17(91.80)	151.00(96.30)	192.17(67.60)	150.83(95.91)
OA-FN				
LowIL	92.67(30.14)	85.17(35.30)	92.92(20.46)	89.08(29.39)
HighIL	182.83(86.08)	182.83(86.08)	181.67(87.26)	167.67(93.83)

Note. YA=Younger adult; OA=Older adult; IL=Information load; SR=Strict rule; LR=lenient rule; LIC=last incorrect; R12=run of 12.

Effect of Information Load

To determine whether participants learned more quickly under low than high information load, it was necessary to remove the data for participants who showed no learning. If all participants had been included, a spurious effect of information load would have emerged due to the large difference between 108 and 240, which are the scores given to those who did not articulate a strict or lenient rule, reach a last incorrect trial prior to the final trial, or have a run of 12 correct trials, for low and high information load, respectively. Therefore, the following criterion was used to select participant data for analysis. Specifically, a participant must have demonstrated learning on three of the following four measures: articulated a strict, articulated a lenient rule, reached their last incorrect trial, and/or reached a run of 12 consecutive trials correct prior to the final five trials of the task. Participants who did not achieve this criterion level of performance and had scores of 103-108 for the low information load condition and 235-240 for the high information load condition on three or more measures were excluded from the analyses. Thirty-six out of 48 total participants were included in the analysis. Twenty were younger adults and 16 were older adults, 13 completed the FP task and 23 completed the FN task, and 15 were in the low information condition while 21 were in the high information load condition. These analyses, like those in the previous sections, did not reveal a significant effect of group or task type on any of the dependent measures (all *ps* $\geq$ .30).

Participants under low information load differed from those under high information load on trials taken to articulate the strict rule, $F(1, 35) = 5.48$, $p = .03$, $\eta^2_p = .16$, showing that those under low information load articulated the strict rule after fewer trials than those under high information load. The information load by group interaction was non-significant, $F(1, 35) = .43$, $p = .52$, $\eta^2_p = .02$, which indicated that number of trials to articulate a strict rule did not vary by levels of information load or group. The information load by task type interaction was also non-significant, $F(1, 35) = .06$, $p = .80$, $\eta^2_p = .00$, showing that number of trials to articulate a strict rule did not vary by information load or task type. The interaction between group, task type, and information load was non-significant, $F(1, 35) = .37$, $p = .55$, $\eta^2_p = .01$, indicating that number of trials taken to articulate a strict rule did not vary by levels of group, task type, or information load.

Participants under low information load also differed from those under high information load on number of trials taken to articulate a lenient rule, $F(1, 35) = 7.47$, $p =$

.01, η^2_p= .21, showing that those under low information load articulated a lenient rule after fewer trials than those under high information load. The information load by group interaction was non-significant, $F(1, 35) = .00$, $p = .98$, η^2_p= .00, which indicated that number of trials to articulate a lenient rule did not vary by levels of information load or group. The information load by task type interaction was also non-significant, $F(1, 35) =$ .00, $p = .95$, η^2_p= .00, indicating that number of trials to articulate a lenient rule did not vary by information load or task type. The interaction between group, task type, and information load was non-significant, $F(1, 35) = .82$, $p = .37$, η^2_p= .03, showing that number of trials taken to articulate a lenient rule did not vary by levels of group, task type, or information load.

Participants under low information load also differed from those under high information load on their last incorrect trial, $F(1, 35) = 18.58$, $p = .00$, η^2_p= .40, showing that those under low information load reached their last incorrect trial after fewer trials than those under high information load. The information load by group interaction was non-significant, $F(1, 35) = 1.40$, $p = .25$, η^2_p= .05, indicating that number of trials to reach their last incorrect trial did not vary by levels of information load or group. The information load by task type interaction was also non-significant, $F(1, 35) = .45$, $p = .51$, η^2_p= .02, showing that number of trials to reach their last incorrect trial did not vary by information load or task type. The interaction between group, task type, and information load was non-significant, $F(1, 35) = .03$, $p = .86$, η^2_p= .00, which indicated number of trials taken to reach their last incorrect trial did not vary by levels of group, task type, or information load.

Participants under low information load differed from those under high information load on trials taken to reach a run of 12 correct, $F(1, 35) = 6.09$, $p = .02$, $\eta^2_p = .18$, which indicated that those under low information load reached a run of 12 correct after fewer trials than those under high information load . The information load by group interaction was non-significant, $F(1, 35) = .11$, $p = .74$, $\eta^2_p = .00$, showing that number of trials to reach a run of 12 correct did not vary by levels of information load or group. The information load by task type interaction was also non-significant, $F(1, 35) = .14$, $p = .72$, $\eta^2_p = .01$, indicating that number of trials to reach a run of 12 correct did not vary by information load or task type. The interaction between group, task type, and information load was non-significant, $F(1, 35) = .06$, $p = .81$, $\eta^2_p = .00$, showing that number of trials taken to reach their a run of 12 correct did not vary by levels of group, task type, or information load. Descriptive statistics for the strict and lenient rules, last incorrect trial, and run of 12 trials correct are shown in Table 3. An alpha of $p \leq .05$ was considered statistically significant for all analyses.

Table 3
Mean (Standard Deviation) Performance on Experimental Task for Learners

Condition	SR	LR	LIC	R12
YA				
LowIL	56.00(40.79)	37.78(29.18)	48.67(32.20)	39.33(12.72)
HighIL	116.64(84.47)	97.91(76.88)	165.45(68.24)	94.73(74.08)
OA				
LowIL	68.83(35.24)	53.83(31.49)	67.17(11.92)	50.83(16.53)
HighIL	126.40(83.39)	126.40(83.39)	150.95(73.31)	97.00(72.90)

Note. YA=Younger adult; OA=Older adult; IL=Information load; SR=Strict rule; LR=lenient rule; LIC=last incorrect; R12=run of 12.

Response Accuracy across Blocks

To determine whether discrimination performance varied across blocks, the proportion of trials correct when the target feature was either present or absent was analyzed using trend analysis. In the low information load condition, there were 18 blocks. Proportion correct was collapsed over each two successive blocks (e.g., 1 and 2, 3 and 4, etc.) to create a total of nine blocks. Within these combined blocks, there were a total of 12 trials; six contained the target feature and six did not. In the high information load condition load, there were 12 blocks, with 20 trials. Ten of every 20 trials contained the target feature, while the other 10 did not. For the trend analysis, two generalized linear models were created, with group and task type as the between subjects factor and block as the within-subjects factor. To assess whether performance varied as a function of feature type (target feature present vs. target feature absent), this variable was added to the analysis as a within-subjects factor. The data for these analyses is shown in Figures 1 - 4.

For low information load, there was a main effect of block at the linear, $F(1, 47) = 29.59$, $p = .00$, $\eta^2_p = .40$, and quadratic, $F(1, 47) = 8.87$, $p = .01$, $\eta^2_p = .17$ levels. The linear trend in the data shows that there was a linear increase in proportion correct over blocks while the quadratic trend shows that there was a positively accelerating learning curve. The main effect at the linear level was qualified by an interaction between block and task type, $F(1, 47) = 3.91$, $p = .05$, $\eta^2_p = .08$, showing that mean proportion of trials correct across blocks varied by task type. There was also a significant interaction between block and task type at the cubic level, $F(1, 47) = 4.04$, $p = .05$, $\eta^2_p = .08$, showing that mean proportion of trials correct across blocks varied by task type. A cubic trend resembles a horizontal inverted “S”. Further, these interactions were qualified by a marginal three-way interaction between group, block, and task type, $F(1, 47) = 3.08$, $p = .08$, $\eta^2_p = .07$. Examination of main effects and interactions between block and task type at the level of group (younger vs. older) revealed that for younger adults, the main effect of block at the linear $F(1, 47) = 13.06$, $p = .00$, $\eta^2_p = .37$, and cubic levels, $F(1, 47) = 5.52$, $p = .03$, $\eta^2_p = .20$, was significant. The interaction between block and task type was also significant at the linear, $F(1, 47) = 7.48$, $p = .00$, $\eta^2_p = .37$ and cubic, $F(1, 47) = 4.67$, $p = .04$, $\eta^2_p = .18$, levels. A main effect of block was also found for older adults at the linear level, $F(1, 47) = 16.54$, $p = .00$, $\eta^2_p = .43$. Unlike younger adults, the interaction between block and task type was non-significant at both the linear, $F(1, 47) = .02$, $p = .88$, $\eta^2_p = .00$, and cubic, $F(1, 47) = .68$, $p = .42$, $\eta^2_p = .03$, levels, indicating that for younger adults but not older adults, performance varied between block and task type. Additionally, there was no main effect of feature type (feature present vs. feature absent) $F(1, 47) = .05$, $p = .83$, $\eta^2_p = .00$, indicating performance did not vary as a function of feature type. The interaction between feature type and group was non-significant, $F(1, 47) = .16$, $p = .69$, $\eta^2_p = .00$, as well as the interaction between feature type and task type, $F(1, 47) = .02$, $p = .88$, $\eta^2_p = .00$, indicating feature type did not vary between younger and older adults or between FP and FN conditions. The three-way interaction between feature type, group, and task type was also non-significant, $F(1, 47) = .10$, $p = .76$, $\eta^2_p = .00$. As Figure 1 shows, younger adults had a higher proportion of trials correct in the first block of the FP condition than the FN condition. However, the proportion of trials correct increased across blocks in the FN condition and surpassed the mean for the condition FP while the mean proportion in the FP condition remained relatively constant. Older adults do not show this pattern between task types, instead performing with relatively equivalent response accuracy in both FP and FN conditions.

Pairwise comparisons between task type and block were conducted to further examine the significant linear and cubic interactions in younger adults. The mean proportion of trials correct was greater in block 1 (p = .01) for the FP as compared to the FN condition, which is reflected in the higher means in the Figure 1 for the first FP block. However, proportion correct was not greater in the FP condition as compared to the FN condition in the last block (p = .23). The difference in correct responses across blocks was significant in the FN but not FP (all $p \geq 1.00$) condition. In the FN condition, when compared to block 1, participants had significantly greater mean proportion correct responses on block 2 (p = .04), 4 (p = .01), 5 (p = .01) and 7-9 (all $p \leq .01$). In sum, younger adults in the FP condition achieved more correct trials in the initial block, and those in the FN condition demonstrated a greater increase in correct responses across blocks, which is likely in part due to the fact that mean proportion correct increased more over blocks for the FN condition than the FP condition, as can be observed in the top half of Figure 1.

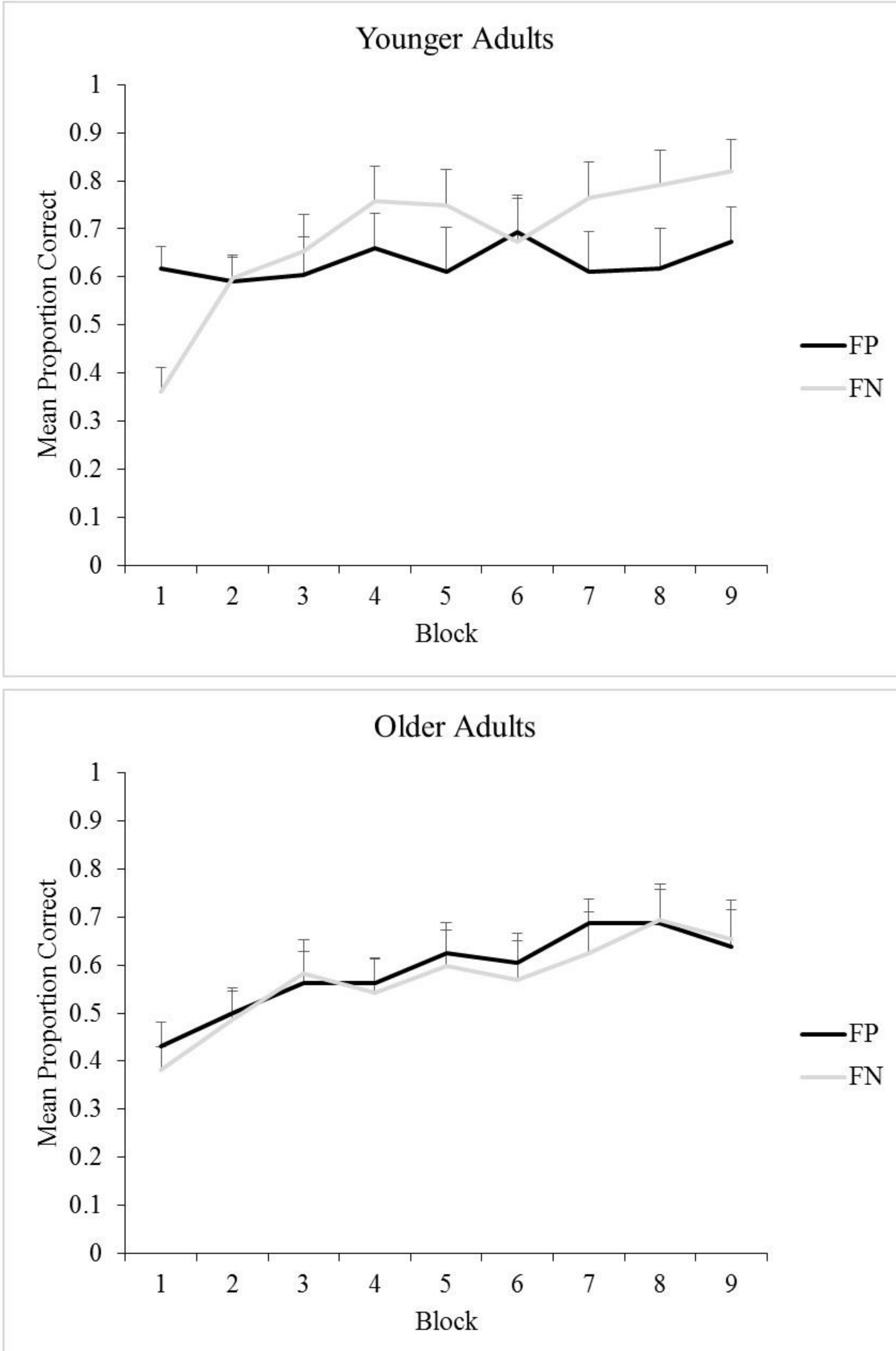
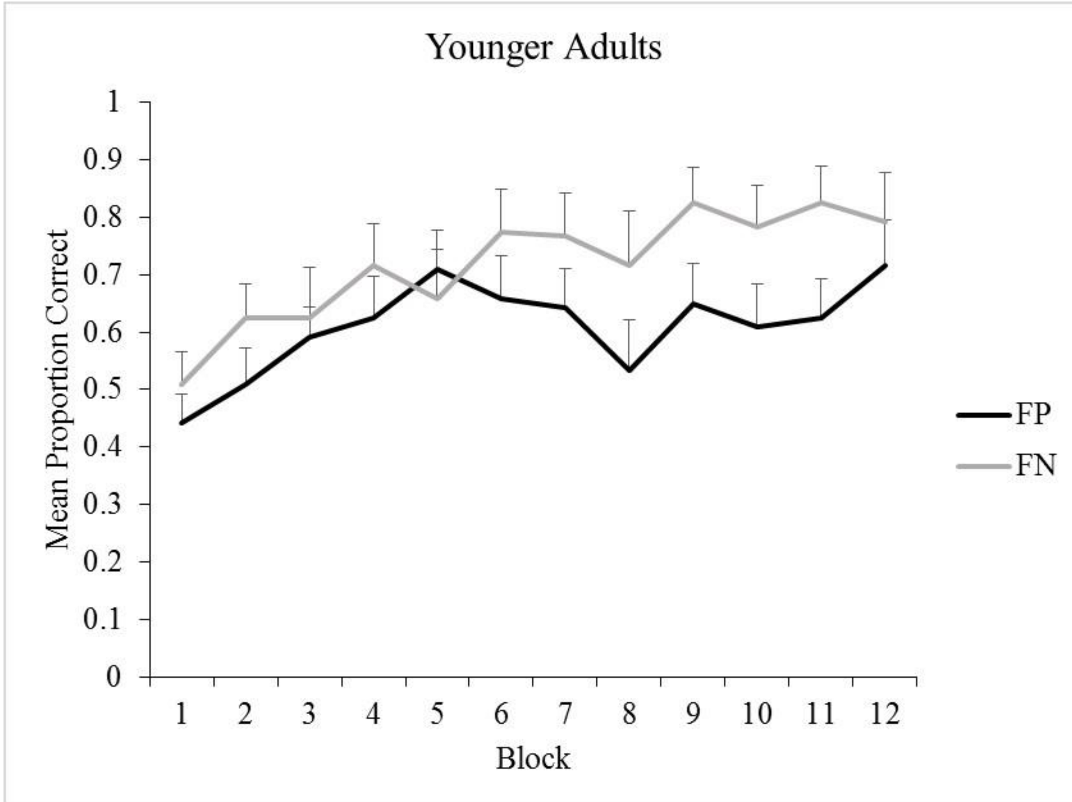


Figure 1. Younger and older adults mean proportion of trials correct and errors in the FP and FN conditions under low information load.

For the high information load condition, there were main effects of block at the linear, $F(1, 47) = 55.45$, $p = .00$, $\eta^2_p = .55$, quadratic, $F(1, 47) = 10.16$, $p = .00$, $\eta^2_p = .18$, and cubic levels, $F(1, 47) = 7.41$, $p = .01$, $\eta^2_p = .14$. The main effect was qualified by a block by task type interaction at the cubic level, $F(1, 47) = 4.15$, $p = .05$, $\eta^2_p = .08$. Further, there was a significant three-way interaction between group, feature type, and task type at the linear level, $F(1, 47) = 6.93$, $p = .01$, $\eta^2_p = .13$. Examination of main effects and interactions between feature and task type at the level of group (younger vs. older) revealed that for younger adults, the main effect of block at the linear $F(1, 47) = 35.51$, $p = .00$, $\eta^2_p = .62$, and cubic levels, $F(1, 47) = 6.69$, $p = .02$, $\eta^2_p = .23$, was significant. These main effects are shown in the top halves of Figures 2 and 3 and demonstrate the linear trend in the data shows that there was a linear increase in proportion correct over blocks. The cubic trend shows that proportion correct positively accelerated initially, negatively accelerated in the middle of the blocks and positively accelerated toward the end of the blocks. The interaction between feature and task type was not significant at the linear level, $F(1, 47) = 2.29$, $p = .14$, $\eta^2_p = .05$. For older adults, a main effect of block was found at the linear, $F(1, 47) = 22.90$, $p = .00$, $\eta^2_p = .50$, and quadratic level, $F(1, 47) = 10.28$, $p = .00$, $\eta^2_p = .31$. The linear trend in the data shows that there was a linear increase in proportion correct over blocks while the quadratic trend shows that there was a positively accelerating learning curve. Unlike younger adults, the interaction between feature and task type was significant at the linear level, $F(1, 47) = 5.72$, $p = .03$, $\eta^2_p = .20$, indicating that for older adult but not younger adults, performance varied by feature and task type.

Pairwise comparisons between feature and task type were conducted to further examine the significant linear interaction in older adults. As the bottom half of Figures 2 and 3 show, proportion of correct trials only marginally increased in the FP condition when the feature was present vs. absent (p = .08), showing that older adults responded correctly more often when the feature was present. In the FP condition, when compared to block 1, older adults had significantly greater mean proportion correct responses on block 7 (p = .00), 9 (p = .02), 10 (p = .05), and 12 (p = .00). In the FN condition, when compared to block 1, older adults had significantly greater mean proportion correct responses on block 7 (p = .02) and 9 (p = .05). In sum, as seen in Figures 2 and 3, younger adults consistently had a greater proportion of correct trials whether the target feature was present or absent in the FN condition. However, older adults displayed relatively equivalent performance when the target feature was present in the FP and FN conditions but got more trials correct in the FN condition when the target feature was absent.



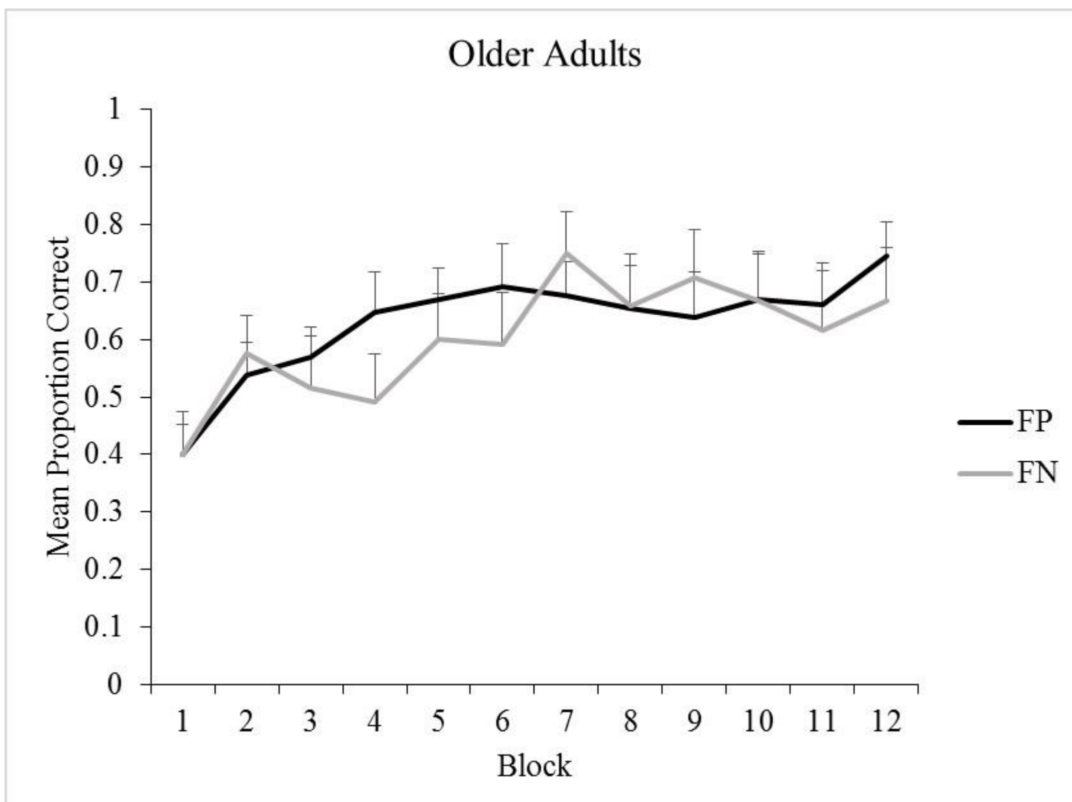


Figure 2. Younger and older adults mean proportion of trials correct and standard errors in FP and FN conditions when the target feature is present under high information load.

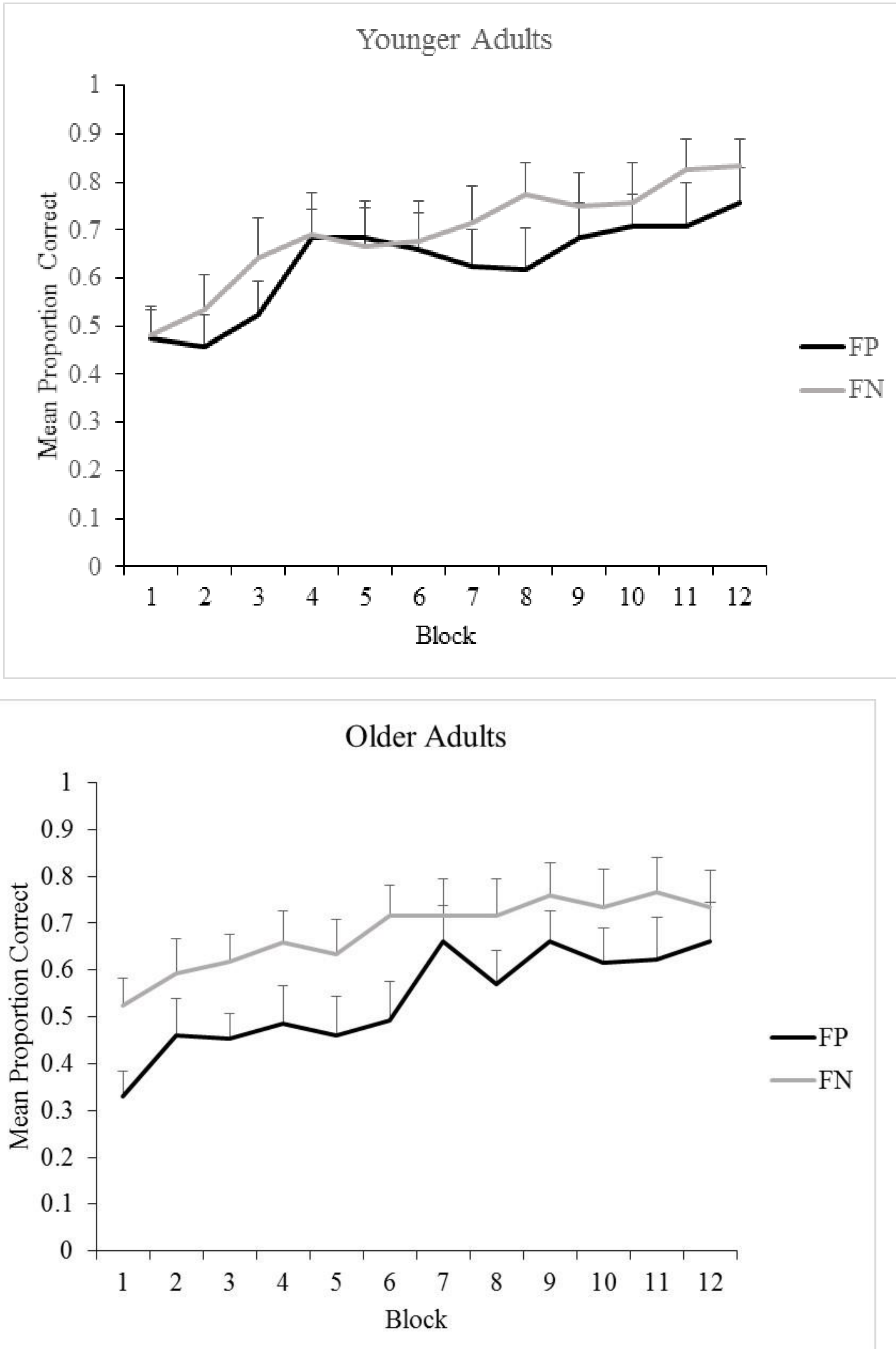


Figure 3. Younger and older adults mean proportion of trials correct and standard errors when target feature is absent in FP and FN conditions when information load is high.

Discussion

The purpose of this study was to examine the effects of aging, task type, and information load on discrimination learning. There were four hypotheses. First, older adults would require a greater number of trials than younger adults to articulate an appropriate rule and to reach a criterion of twelve trials correct in a row regardless of task type or information load. This was not supported by the results, which instead showed no age difference in either measure. Second, both younger and older adults should articulate an appropriate rule after fewer trials and reach their last incorrect trial after fewer trials under low information load than under high information load for both FP and FN learning. This hypothesis was supported, as participants who learned were more likely to articulate a strict and/or lenient rule, reach their last incorrect trial and reach a run of 12 trials correct more quickly under low information load as compared to high information load.

The third hypothesis was that younger adults should show an FNE when information load was low but not when information load was high. This was not supported by the results for the primary dependent measures, which showed that there was no effect of task type or information load on rule articulation, last incorrect trial or number of trials taken to reach a run of 12 correct. However, the results of the trend analysis did support the hypothesis. Under low information load, younger adults initially had a greater proportion correct in the FP than FN condition, but throughout the task, proportion correct in the FN condition continually increased until it surpassed the mean proportion correct in the FP condition. In contrast, older adults had approximately equal proportions correct in both FP and FN conditions. Thus the trend analysis demonstrated differential performance between younger and older adults under low information load, as younger adults improved more on the FN than FP task over blocks, while older adults improved in both conditions relatively equally. Although there was no significant FNE for younger adults as predicted for rule articulation, last incorrect trial, and run of 12 trials correct, this trend analysis provides some evidence that younger adults had greater learning in the FN task. This pattern is consistent with Fiedler et al., (1988) who found that under low information load performance was better in the FN as opposed to FP task. However, there was no significant difference between FP and FN conditions on task performance under high information load for younger and older adults. This is inconsistent with Fiedler et al. who found that under high information load performance was better in the FP as opposed to FN task.

Fourth, it was expected that older adults, unlike younger adults would show a FPE in both information load conditions. This was not supported by the results for the primary dependent measures, which showed no effect of task type or information load for older adult rule articulation and trials taken to reach their last incorrect trial or run of 12 trials correct. In the trend analysis, for the FP task, older adults responded correctly more often when the feature was present rather than absent although this effect was small and only marginally significant and younger adults had an equal proportion correct for feature present and absent trials. In contrast, the trend analysis showed that in the FN task under high information load, younger adults had an equal proportion correct regardless of whether the target feature was present or absent, but older adults were more likely to respond correctly to a trial when the target feature was absent and incorrectly when it was present, suggesting they were only partially learning how to respond correctly to the trials as compared to younger adults who responded equivalently for each feature type condition. Under low information load, there was no difference in proportion correct based on the target feature's presence or absence for both age groups in either FP or FN conditions. Thus, under high information load, performance was more similar between age groups for the FP than the FN task. This age difference suggests that older adults struggled more than younger adults in learning to respond correctly in a FN task, which is consistent with the findings of Mutter et al., (2006), who showed that older adults took more trials to learn the FN rule than younger adults. This provides partial support for the hypothesis that older adults, unlike younger adults would show a FPE in both information load conditions, because older adults did not demonstrate a FNE in their proportion correct across information load conditions.

These findings are inconsistent with previous literature for the primary dependent measures yet more consistent for the trend analysis, which demonstrated a FN bias under low information load for younger adults (Fiedler et al., 1988). There are several reasons why an age difference and FP bias for the primary dependent measures were not replicated in this experiment. The first may be differences in the difficulty of the task between studies. Previous research employed a simultaneous discrimination task with four stimuli (Mutter et al., 2006), so participants always saw all four stimuli at once for each trial. The current study employed a successive discrimination task with either four or six stimuli, and participants observed only three stimuli per trial. Therefore, even in the four stimuli, low information load condition, the task was considerably more difficult than a simultaneous discrimination task. This could have eliminated the age difference in the FPE because even in the FP condition the task was simply too difficult for both groups. Only twenty-six of 49 participants articulated a strict and/or lenient rule and only ten completed the FP task; when including those who had met either strict rule articulation, lenient rule articulation, reached their last incorrect trial, or had a run of 12 trials correct prior to the final five trials of the task, this number increased to 31 total, with 13 having completed the FP task. The fact that many participants regardless of age or condition did not demonstrate learning supports the notion that the task was difficult for both age groups.

Second, and related to the issue of task difficulty, the successive discrimination task may have increased WM demands during learning more than the simultaneous discrimination task. Mutter et al., (2006) included a WM-loaded younger adult group and found they performed like older adults, implicating declining WM capacity as a factor in the different performance between age groups. Although the current study did not include WM loaded younger adults, the difficult successive discrimination task used here naturally placed a greater demand on WM than a simultaneous task. In a successive discrimination task, participants must remember which stimuli have been presented before and whether they were associated with a correct or incorrect response in order to learn what makes the trials correct or incorrect. In fact, many participants, younger and older, reported that they had difficulty recalling which stimuli they had seen in previous trials but they stated they needed to recall them to know how to respond to upcoming trials. Participants must also recall correct and incorrect responses in a simultaneous task, but the WM demand is lower because all stimuli are always presented. In sum, the heightened task difficulty and increased WM demands may have attenuated age differences that are typically seen in a discrimination learning task.

The FNE under low information load and FPE under high information load reported by Fiedler et al. (1988) also failed to replicate for younger adults for the primary dependent measures. Fiedler et al. determined the rule had been learned using a dichotomous measure based on when a participant had achieved 12 consecutive trials correct and at this point the task was stopped. Participants whose score fell below the group median for 12 consecutive trials correct were classified as non-learners while those at or above the median were classified as learners. Although a run of 12 consecutive trials was also a dependent measure in the present study, participants were only recorded as having learned the rule if they had stated a rule that could be categorized as strict and/or lenient and they were required to complete all trials no matter how many they had gotten correct. It is important to note the number of trials taken to reach a run of 12 trials correct was non-significant for all conditions in the current study, even when this measure was used dichotomously to score participants as learning or not learning the rule. Therefore, while the discrepancy between the articulation measures in the current study and Fiedler et al. may be due to differences in how rule learning was operationalized, it remains unclear as to why the dichotomous measure based on the run of 12 trials correct failed to replicate their findings. However, in the current study multiple participants reached a run of 12 correct and afterwards made errors on subsequent trials, which suggests that although they may have had some knowledge of the rule, it was incomplete. Twelve consecutive trials correct may not be sufficient to infer discrimination learning has occurred, and the study by Fiedler et al. is inconclusive on this matter as trials stopped immediately following 12 consecutive correct responses.

There are also differences in the methods used to determine what participants thought the rule was in the current study and Fiedler et al. (1988). They asked participants after ending the task what they believed the rule was and under low information load in the FN condition, their participants often reported that the rule was not the absence of a stimulus, but rather the presence of multiple stimuli. Therefore, the FNE reported by Fiedler et al. was not based solely on participants who learned a strict FN rule, but also on those who learned rules involving a configuration of present stimuli. In the current study, participants were asked to report a rule as soon as they thought of one during the task and they could report as many rules as they wanted throughout the task. Participants were separated based on whether the rule they articulated was the actual rule (strict), one that would work for all trials (lenient) even if it was not the actual rule, whether the rule was invalid (no learner), or if no rule was articulated during the task (no learner). The current study therefore defined rule learning more explicitly in the form of requiring verbal articulation, while Fiedler et al. did not distinguish between the actual rule and rules that would work but were not the actual rule. In other words, Fiedler et al. defined the rule in terms of leniency rather than a strict criterion. Although verbal rule articulation might not be the most sensitive measure of discrimination learning, neither the current study nor Fiedler et al. demonstrated a FNE in terms of actual FN rule articulation.

There is a clear discrepancy between the results of the primary dependent measures and the trend analysis. This is likely due to rule articulation not being the most reliable measure of discrimination learning. Rule articulation by definition requires explicit knowledge of the rule, whereas correct and incorrect responses can reflect both explicit or implicit learning. Further, participants may differ in when they choose to articulate a rule. For example, they may know the rule at trial 40 but refrain from stating that to the researcher until testing it thoroughly, which adds variability to the results. Some participants might reach a run of 12 trials correct, which would qualify in the Fiedler et al., (1988) study as learning the rule, but they might never actually articulate a rule. In the current study, this would disqualify the participants from being classified as learning the rule. Here rule learning was operationally defined as either a strict or lenient verbalization of the rule, which relies on participants articulating a rule as soon as they think of one. In contrast to rule articulation, the trend analysis suggests younger adults had greater learning in the FN than FP task under low information load, which is what would be expected given the results of Fiedler et al. It is clear that the pattern of responding during training revealed a different result than rule articulation, which supports the notion that rule articulation might not be the most reliable measure for the current study.

Finally, the stimuli used in the current study differ slightly from those used by Fiedler et al., (1988). In the current study three solid black stimuli were presented adjacent to each another inside a frame, whereas in Fiedler et al. the three stimuli were represented as dotted lines and a blank space was randomly positioned between two of the three stimuli. The stimuli in the present experiment are identical to those used by Mutter et al. (2006) and were represented as solid black shapes rather than dotted lines to make them easier to perceive. The blank space was not included in the current study due to a concern that it would lead participants to focus on stimulus absence. Importantly, the stimulus display itself should not lead participants to think about presence or absence of the target FP or FN stimulus. Therefore, it could be the case that the blank spaces in Fiedler's study made the FN task easier, which may explain in part why the run of 12 trials correct and the lenient rule measure in the current study failed to replicate Fiedler's findings.

The trend analysis results indicated that younger adults displayed an FN bias under low information load whereas older adults showed no bias, and this finding can be at least partially explained by inductive reasoning theory. According to this theory, hypotheses are created and their validity is assessed based on feedback that confirms or denies those hypotheses (Hearst, 1991; Levine 1966; Mutter et al., 2006). Older adults generally perform worse than younger adults on tasks that require inductive reasoning and this deficit is related to declines in WM capacity. As stated in the introduction, FP discriminations are less complex than FN discriminations and are therefore solved faster (Mutter et al., 2006). Given the findings of Fiedler et al., (1988) who showed younger adults displayed an FNE under low but not high information load, it was expected that younger adults would display an FNE under low but not high information load. On the other hand, the deficit in inductive reasoning related to WM for older adults led to the expectation older adults would display an FPE under both high and low information load.

The level of inductive reasoning needed to successfully generate a rule was conceivably less resource demanding under low versus high information load for younger adults, but with deficits in inductive reasoning that are likely related to lower WM capacity, older adults did not benefit from low information load. If older adults have these deficits in comparison to younger adults, reducing information load by presenting three of four instead of three of six stimuli would not reduce task demands as much for older adults as for younger adults. In further support of this interpretation, Sainsbury (1971b) showed that when presenting three of four stimuli, nine-year old children showed no FPE but five-year old children did, leading to the conclusion that a certain level of task complexity is needed to produce a FP bias. Fiedler et al. similarly concluded the FNE was produced due to invariant patterns under low information load. The low information load condition is therefore less complex than high information load and produced a FN bias in terms of proportion of correct responses for younger adults. However, it failed to produce a difference between FP and FN conditions in older adults as task difficulty seems to increase throughout adulthood for tasks requiring inductive reasoning (Hartman et al., 2001; Mutter et al., 2006; Rhodes, 2004). Low and high information load conditions were likely more complex for older adults than younger adults due to attenuated inductive reasoning.

Summary, Limitations and Future Directions. In sum, results from the primary dependent measures did not support the hypotheses and were inconsistent with prior literature (Fiedler et al., 1988; Mutter et al., 2006) while the trend analyses provided partial support for the hypothesis and results more consistent with those of Fiedler et al. The current study does not support an age difference in articulation of FP and FN rules, but as noted previously this may be related to the difficulty of a successive discrimination task. In addition, a FNE was not shown in articulation for younger adults under low information load, although the FNE reported by Fiedler et al. was not based on the same criteria as the current study. However, younger adults did show greater learning in the FN versus FP task under low information load when proportion correct was the dependent measure, which is suggestive of an FN bias.

One limitation of this study was that it was necessary to use convenience sampling for both younger and older adults for both age groups. This type of sampling was necessary due to the limited time available for data collection and is typical for studies of cognitive aging. However, it did not appear to have influenced the results by creating a non-representative sample. The individual difference measures indicated that as expected, younger adults outperformed older adults on measures of processing speed and WM but older adults outperformed younger adults on the measure of verbal knowledge. This shows that participants were representative of their respective age groups in terms of cognitive abilities most relevant to the experimental task.

Future research should explore the effect of varying information load in a simultaneous discrimination task to determine if it differs from successive discrimination. A high information load, simultaneous discrimination task should be more difficult than a low information load task, yet both should be easier than high and low information load versions of successive discrimination tasks. Additional measures to identify rule learning should also be used, rather than only explicit rule articulation. Further, participants may be more willing to articulate the rule they are thinking of at the moment it comes to mind if they can state it to themselves rather than the researcher who they may feel uncomfortable with reporting every rule they hypothesize. This is especially so because they were aware the researcher knew the rule and recorded their responses verbatim. For example, the task could be programmed to use a microphone and when participants believe they have discovered a rule they could press a key to indicate this and then speak into the microphone. This would allow the participant to complete the task alone and also log the exact trial at which rules are articulated in the data file. Under these conditions, the participant should be more likely to articulate his or her thoughts as they are experienced because the social pressure of the researcher recording everything they say is no longer present.

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Appendix A

Example of Task Stimuli