# Using Goal-Incidental Attributes to Assess the Relationship Between Selective Attention and Attribute Centrality

**Seth Chin-Parker (chinparkers@denison.edu)**
Department of Psychology – Denison University, 100 W College St.
Granville, OH 43023 USA

## Abstract

As we interact with the world, we learn how to allocate our attention effectively to achieve our goals. In this study, participants' eye movements were tracked as they engaged in a same-different task with novel stimuli. Participants then completed a goal-directed task using physical copies of the items. In the task, the goal-relevance of the attributes varied. This was followed by a second block of the same-different task. We analyzed how attention to the goal-relevant, goal-incidental, and goal-irrelevant attributes of the items shifted from the initial block of the same-different task to the second. The gaze patterns clearly distinguished between the goal-relevant and goal-irrelevant attributes. However, there was no distinction between the goal-relevant and goal-incidental attributes. We discuss the implications for understanding how goal-directed interactions shape attentional allocation and how this relates to what people learn about the items.

**Keywords:** selective attention, category learning, goals

In order to operate effectively within a particular context, we must work with the available information in such a way that allows us to reach our goals. A critical component of this involves organizing events and objects in terms of categories we have learned in such a way that we can access information from past experiences to guide our reasoning and actions. For instance, sitting down for a meal often involves a rich and dynamic visual field. It is important to be able to quickly differentiate plates and bowls and pots and forks and dinner guests and then be able to plan requests and movements in such a way that we behave in an appropriate manner for the type of meal being served. All of this requires flexible and efficient processing, especially in terms of how we select information available in the environment to guide our actions.

Attentional allocation depends on various factors (e.g., Theeuwes, 2019). If there a bright candle on the table or an errant dinner roll flying toward you, you are likely to attend to those salient pieces of information. We also rely on our prior knowledge; we know a lot about table settings and what takes place during a dinner, and this will also guide our attentional allocation. It also matters what you have recently attended to during the meal as we tend to prioritize information that has recently been attended to. Because we are limited in terms of how much information we can process at any moment, understanding how these different factors contribute to our attentional allocation is important.

Theories of category learning reflect the idea that there is a tight coupling between our knowledge of categories and our selective attention (for recent commentary see Minda et al., 2024; Unger & Sloutsky, 2023). As we engage with instances from categories, attributes that are most important to those interactions become highlighted within the category representation. Imagine your first experience learning to categorize forks and spoons. Initially, you might consider the shape of the handle or whether it has an engraved flower to be as important as the shape of the head of the utensil. However, if you are tasked with sorting them into a utensil drawer, separating the forks and spoons appropriately, you would learn to ignore the flower engraving and attend to the head of the utensil. Simply put, when categorizing the utensils, you would come to recognize the engraving as goal-irrelevant information and the shape of the head of the utensil as goal-relevant information. To account for the variable importance of the goal-relevance of attributes, models of category learning have employed various means such as attention-weighting (e.g. Kruschke's ALCOVE model, 1992) or clustering mechanisms (e.g. SUSTAIN, Love, Medin, & Gureckis, 2004) to capture the effects of selective attention on category learning. However, an influential dual system model, COVIS, proposes that only an explicit, rule-based system engages selective attention in this manner (Ashby & Valentin, 2017).

The premise that goal-relevant attributes are learned more fully than goal-irrelevant attributes has been widely supported by behavioral study and has important implications for how we understand category learning (e.g. Markman & Ross, 2003). In the past two decades, a robust literature has emerged examining various aspects of the role of selective attention in category learning using eye-tracking methodologies (e.g., Blair et al., 2009; Dolguikh et al., 2021; Hoffman & Rehder, 2010; McColeman et al., 2019; Rehder & Hoffman, 2005). A recurring assumption among these studies is that selective attention as measured using an eye-tracking methodology represents the attentional weights associated with the attributes within the acquired category knowledge. Blair et al. (2009) explicitly consider whether this supposition is warranted in the discussion of their research, and conclude:

> "… there is evidence that measures of gaze match dimensional attention predictions in categorization tasks, both qualitatively—eye movements show that irrelevant information is not fixated—and quantitatively—gaze data correlate with dimensional weight values produced by fitting models to data. These facts justify a fairly straightforward mapping between measures of gaze and dimensional attention."

If this relationship holds, eye-tracking methodologies offer a valuable tool as a sensitive and implicit measure of conceptual knowledge.



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However, recent research into goal-directed concept acquisition challenges this assumption. Chin-Parker and colleagues found evidence that attentional allocation alone is not sufficient to account for attribute centrality (Chin-Parker & Birdwhistell, 2017; Chin-Parker et al., 2025). In these studies, they differentiated between goal-relevant, goal-irrelevant, and goal-incidental attributes.

Imagine that your goal is to successfully eat the food put in front of you. You need to select the correct utensil, and that decision will depend on whether you are served soup or pasta. The head shape is goal-relevant because it directly impacts the decision of whether you grab a fork or a spoon. Thus, it is critical to attend to that attribute of the utensil. There is no need to attend to an engraving of a flower on the utensil as it is a goal-irrelevant attribute and does not impact whether you will attain your goal. This fits with the notion of goal relevance as it has been addressed above. However, in this situation, you must also attend to the shape of the handle of the utensil to successfully pick it up. In one sense, you could consider the handle shape to be goal-relevant because it must be attended to in order to complete the task. However, the handle shape less central to the task at hand—selecting the proper utensil to eat your meal—and the interaction with the handle shape is not differentiated in terms of the category as both forks and spoons have handles that are used similarly. Chin-Parker and colleagues identified these types of attributes as goal-incidental attributes to differentiate them from goal-relevant and goal-irrelevant attributes. A goal-incidental attribute, like the handle shape, must be attended to, but it does not provide information that is specifically germane to the task at hand (i.e., deciding whether to pick up a fork or a spoon). Consideration of goal-incidental attributes is important because they allow a test of the assumption that there is a tight linkage between selective attention and how central the attribute is within the category representation.

Chin-Parker and colleagues proposed the goal-framework hypothesis to differentiate between how goal-relevant and goal-incidental attributes are incorporated into the category knowledge. Briefly, the goal provides structure to the interaction with the attributes of the item and therefore contributes to how they are organized within the acquired knowledge. In this manner, the relevance of the attribute to the goal determines the centrality of the attribute such that selective attention alone does not determine its weight within the category representation. Across two studies, using different tasks and measures, the results supported the notion that the goal-relevant attributes were more important to category-based reasoning (e.g., making similarity judgments, rating the category goodness of instances, and sorting instances into groups) than goal-incidental attributes (Chin-Parker & Birdwhistell, 2017; Chin-Parker et al., 2025). Because participants had to attend to the goal-incidental attributes during the task, they did show increased knowledge of the attributes compared to attributes that were goal-irrelevant. However, the evidence was clear that selective attention was not solely responsible for how the attribute information was encoded within the category knowledge.

The current study extends that research by examining eye-gaze patterns associated with goal-relevant, goal-irrelevant, and goal-incidental attributes. Initially, participants engage in a relatively simple task while we track their gaze – they are shown images of two novel items, one after the other, and asked whether the items are the same or different. This task was chosen because it prompts the participant to look across all the attributes of the items equivalently to determine whether they change or not from the target to the comparison item. Then participants interact with physical versions of the items completing the goal-directed tasks described in Chin-Parker et al. (2025). Following completion of those tasks, the participants complete another block of the same-different trials. In Exp. 1, the primary attributes of the items are either goal-relevant or goal-irrelevant. In Exp. 2, the primary attributes are either goal-relevant or goal-incidental.

Based on the behavioral results noted prior, if there is a correspondence between the eye gaze patterns and the category knowledge, participants should show a shift in their attentional allocation from the first block of the same-different trials to the second block, and this shift should reflect the goal-relevance of the attributes. Specifically, there should be an increase in attention to goal-relevant attributes that is significantly larger than any increase in attention to the goal-incidental attributes. The goal-irrelevant attributes should be attended to less after completing the goal-directed task. However, there is the possibility that the eye-tracking measures will reflect the attentional allocation during the task. If that is the case, the eye-tracking measures should find that attention to the goal-relevant and goal-incidental will be similar since they had to attend to both types of attributes to complete the task. So, if selective attention dissociates from the category representation, we should find that the goal-relevant and goal-incidental attributes show similar increases in attentional allocation while the goal-irrelevant attributes are attended to less across the blocks.

## Experiment 1

### Methods

**Design.** Participants were randomly assigned to either the head-relevant (HR) or interior-relevant (IR) task condition. The experiment consisted of three phases. All participants completed the initial block of the same-different task followed by the goal-directed task which varied by condition. Finally, all participants completed the second block of the same-different task. The primary measure is dwell time to the attributes during the two blocks of the same-different trials.

**Participants.** Participants were introductory psychology students who received course credit for their participation. All participants reported that they had normal or corrected-to-normal visual acuity. No demographic information was recorded. We anticipated a large effect size given the robust difference between conditions reported in earlier studies using these goal-directed tasks, so we set a minimum sample size of 20 participants per condition (based on G*Power calculations for achieving a power of .80). We collected data from 63 participants but removed 13 participants (5 in the HR condition, 8 in the IR condition) because they had eye gaze data missing from more than 40% of their trials. This left 26 participants in the HR condition and 24 in the IR condition.

**Materials and Procedure.** The participants interacted with and made decisions about a set of novel objects we referred to as "keys" (see Figure 1 for the keys used during the goal-directed task). Each key had two primary attributes – the head shape and interior shape. The head shape consisted of either vertical or horizontal slots, and the interior shape consisted of either diagonal or perpendicular protrusions. Participants viewed images of the keys during the same-different task and interacted with physical copies of the keys during the goal-directed task. The images of the keys used for the same-different task were created using the same computer aided design (CAD) software that was used in printing the physical keys. The keys for the goal-directed task were approximately 10 cm by 6 cm by 1 cm in size and were made of ABS plastic.

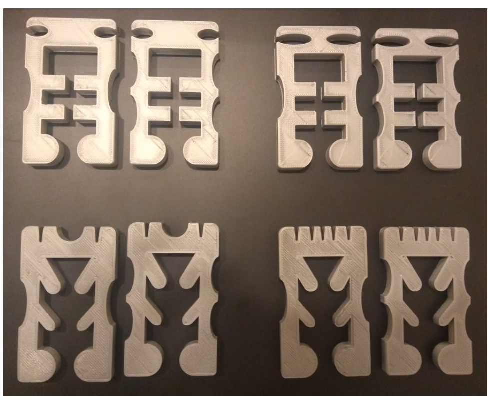

Figure 1: Keys used during the goal-directed task

The experiment started with the participant completing the same-different task at a computer workstation. After the eye-tracking unit was calibrated, the participants completed the first block of the same-different task. Each trial of the same-different task followed the same structure. First, a fixation point appeared in one of six randomly selected locations on the screen. These points were equidistant from the center of the screen and outside of the area where the target image would appear. After the participant attended to the fixation point, it disappeared, and an image of the target key was displayed in the center of the screen for 2000 ms. After the target key disappeared, another fixation point was displayed, again appearing at one of six possible locations. Finally, the comparison key was presented in the center of the screen until the participant response. Using a handheld device, the participant indicated whether they considered the comparison key to be the same or different compared to the target key. During the first block, the participants completed 16 same-different trials. There were four *same* trials where the same image was displayed as the target and comparison keys. There were four *different* trials where the head and interior attributes differed between the target and comparison images. There were four *same head* trials in which the head shapes of the target and comparison keys matched but the interior shapes were different. There were four *same interior* trials in which the interior shapes of the target and comparison keys matched but the head shapes were different. The 16 trials were randomly presented during each block.

Following the first block of the same-different task, participants began their assigned goal-directed task. Participants used physical copies of eight of the keys seen during the same-different task (see Figure 1). Four of the keys had a head shape with vertical slots and an interior with diagonal protrusions. The other four keys had a head shape with horizontal slots and an interior with perpendicular protrusions.

The participants moved to an adjacent table and were given instructions for the goal-directed task. Two task boards were placed in front of the participant. The boards were approximately 20cm by 35cm and made of wood. On each board were metal protrusions that the key could be fit onto (see Figure 2). The task was the same in both conditions; participants had to place the key onto the key frame, use the key to slide the transport exposing a button that they could then press with a simple metal tool to turn on some lights indicating the task had been successfully completed.

The boards varied between the conditions and were designed so that each key would fit onto only one of the two boards. In the HR condition, keys with a head shape featuring horizontal slots would fit onto one of the boards, while keys with vertical slots would fit onto the other board. In the IR condition, keys with perpendicular protrusions in the interior fit onto one of the boards, and keys with diagonal protrusions fit onto the other board. In the HR condition, the boards were neutral regarding the interior shape, and in the IR condition, the boards were neutral regarding the head shape. In this manner, only one attribute of the key, either head shape or interior shape, was relevant to the task while the other attribute was irrelevant to the task. Participants completed 16 trials of the task, receiving each of the eight keys twice in a random order.

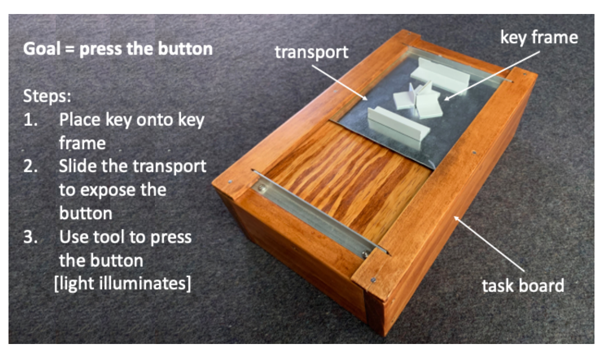


Figure 2: Overview of an example task board used in the goal-directed task. This example is from the IR condition.

Once the participant completed their assigned goal-directed task, they returned to the computer workstation and repeated the 16 trials of the same-different task.

**Eye-Tracking Apparatus and Methodology.** Eye gaze data were recorded using an Eyelink Portable Duo system. The eye-tracking camera was positioned in front of a 17" laptop screen, set to a 1920x1080 resolution at 240 Hz. Participants placed their chin on a rest positioned 57cm from the camera. The camera tracked pupil and corneal reflection from the right eye. Experimenter Builder software was used to handle stimulus presentation and to record participant responses. Participants completed a 9-point calibration routine before each block of the same-different tasks.

## Results

The initial analyses focus on the distribution of gaze when the target key was displayed during the same-different task and how that distribution changes from the first block of the same-different trials to the second block. This measure was used because the target key had a consistent display time (it was not dependent on participant response). Only dwell time measures are reported due to space constraints (the fixation results closely match the pattern of dwell time). I predicted that participants would allocate their gaze evenly across the images of the keys during the initial same-different session but that pattern would shift during the second block of the same-different trials. Participants in the HR condition should attend to the head attribute more than they did in the initial block while participants in the IR condition should attend more to the interior attribute of the keys.

In the initial block, participants in the head relevant condition fixated on the images for 1381 ms (SD = 59.77) while the participants in the interior relevant condition fixated an average of 1368 ms (SD = 85.81). In the second block, those averages were 1382 ms (SD = 55.00) and 1365 ms (SD = 100.87) respectively. There was no difference between conditions, between blocks, and no interaction between condition and blocks (all *F*s < 1.00, *p*s > .48). These results indicate that throughout the experiment, participants had similar dwell times while viewing the target items.

The main analyses focus on the distribution within the two AOI (the head attribute and interior attribute) across the conditions and sessions (see Figure 3). First, there was a main effect of the condition, $F(1, 48) = 5.16$, $p = .03$, $\eta_p^2 = .10$. Overall, participants in the HR condition looked within the AOI for significantly more time than the participants in the IR condition. There was also a main effect of the block, $F(1, 48) = 11.98$, $p = .001$, $\eta_p^2 = .20$. Participants looked within the two AOI for more time during the second block of same-different trials. There was a clear effect of the attribute, $F(1, 48) = 115.85$, $p < .001$, $\eta_p^2 = .71$. On average, participants looked within the interior AOI longer than the head AOI. The block by condition and the attribute by condition interactions were not significant. However, there was a significant block by attribute interaction, $F(1, 48) = 5.36$, $p = .03$, $\eta_p^2 = .10$, indicating an overall shift in the dwell time away from the interior AOI to the head AOI in the second block of the same-different trials. Finally, the predicted three-way interaction was present, $F(1, 48) = 11.45$, $p = .001$, $\eta_p^2 = .20$. In the second block of the same-different trials, the participants in the HR condition tended to look longer at the head AOI and spent less time looking at the interior AOI while participants in the IR condition looked more within the interior AOI and did not change how long they looked at the head AOI.

Briefly, both conditions looked equivalently at the head attribute in the first block of the same-different trials, but the head relevant condition showed a significant increase in looking time to that attribute in the second block while the participants in the interior relevant condition showed no such increase. The participants in the head relevant condition decreased their looking time to the interior of the keys post-task while the participants in the interior-relevant condition slightly increased their looking time.

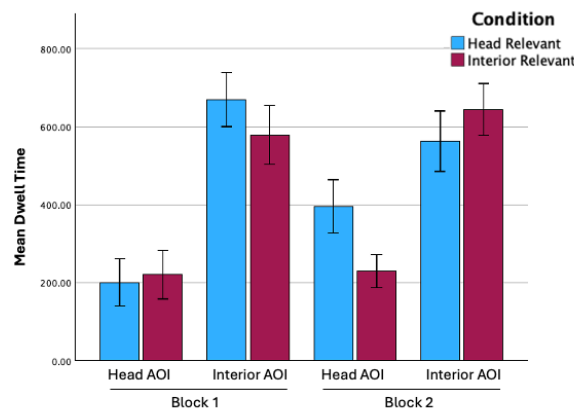


Figure 3: Dwell time averages from Exp. 1

Although not intended, there were clear effects of visual salience of the attributes. In general, participants tended to look more at the interior of the keys compared to the head. This differentiation could be accounted for in a couple of ways. There could have been a tendency to look first at the center of the image which would have been the interior attribute of the key. It is also possible that the interior shape of the key was more interesting due its shape or complexity. Regardless of why it occurred, participants consistently had longer dwell times to the interior of the key. It impacted the results of Exp. 1 because participants in the IR condition already were biased towards looking at the interior of the key instead of the head before completing the goal-directed task. They showed no change in their attentional allocation to the head, because they weren't looking at it much to begin with. There is only a small increase in dwell time for the interior shape since they were already looking at it quite a bit during the first block of the same-different task. The HR condition more clearly shows the expected changes in the gaze patterns. Participants in the HR condition were not looking towards the head shape much before the goal directed task, but effectively doubled their looking time to that attribute following the goal-directed task. The participants in the HR condition also show the expected decrease in dwell time for the interior shape as it was goal-irrelevant during their goal-directed task.

During the goal-directed tasks, the participants are learning how to allocate attention effectively to accomplish the task they have been assigned. The open question is whether the shift in the gaze patterns reflects the relationship of the attributes to the goal in the acquired category knowledge. To examine this question, we introduce a variation of the paradigm that includes goal-incidental attributes. The participant must attend to these attributes to compete the task, but the attribute itself does not directly impact the manner in which the goal is achieved.

## Experiment 2

### Methods

**Design.** Participants were randomly assigned to either the interior-relevant (IR) or interior-incidental (II) condition. The general design of the experiment was identical to Exp. 1 in that participants completed an initial block of the same-different task, followed by a goal-directed task, followed by the second block of the same-different task. Again, the dwell time to the attributes during the two blocks of the same-different trials is the focus of the analyses.

**Participants.** We collected data from 78 participants. All participants were students in an introductory psychology course and reported that they had normal or corrected-to-normal visual acuity. We set a target sample size of 40 participants per condition because we anticipated a smaller effect size than found in Exp. 1 (based on G*Power calculations for achieving a power of .80). The data for 14 participants (9 in the IR condition, 5 in the II condition) were removed because of missing data from more than 40% of their trials. This left 28 participants in the IR condition and 36 participants in the II condition.

**Materials and Procedure.** The materials and procedures used in Exp. 2 were much like those from Exp. 1 except for two critical alterations. First, participants in both conditions used the same two task boards. The task boards were redesigned so that there were two steps to the task. First, the key was fit onto the key frame based on the head shape of the key. Each key fit onto one of the two boards. In this way, the head shape was a goal-relevant attribute for all participants. Once the key was in place, the participant could slide the transport (as in Exp. 1), and an opening in the transport beneath the key allowed access to the button. This aspect of the task differed from the previous experiment where the button was uncovered above the key. The second critical change was that participants were given two tools they could use to press the button. The tool had to be inserted through the interior of the key to push the button and complete the task. For the IR condition, the interior shape of the key determined which key the tool would fit. One tool fit through the keys with horizontal projections, and the other tool fit through the keys with diagonal interior projections. In the II condition, both tools could fit through either of the keys. In the II condition, the participant must attend to the interior shape of the key to navigate the tool through, but the interior shape does not factor into which tool could be used. See Figure 4 for a diagram depicting how the tool shapes related to the interior shapes of the keys.

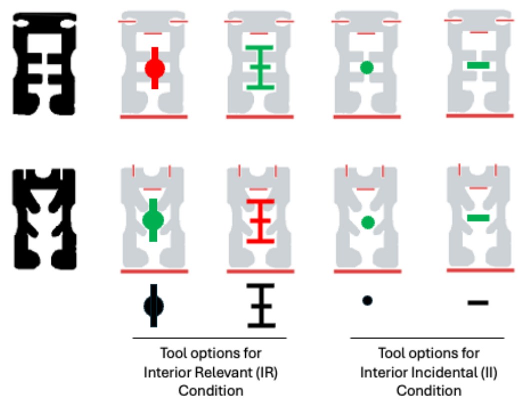


Figure 4: Schematic of the relationship between key types and tools used in Exp. 2

### Results

In Exp. 2 the head attribute is goal-relevant for all participants and the interior attribute varies by condition whether it was goal-relevant (IR condition) or goal-incidental (II condition). The analyses are the same as the ones completed for Exp. 1.

In the first block, participants in the IR condition fixated on the target image an average of 1365 ms (SD = 70.11) while the participants in the II condition fixated an average of 1384 ms (SD = 80.95). In the second block, those averages were 1383 ms (SD = 73.49) and 1380 ms (SD = 67.32) respectively. There was no difference between the conditions overall, and the averages during each block were not different (both $F$s < 1.85, $p$s > .18). However, there was a condition by block interaction, $F(1, 62) = 4.19$, $p = .045$, $\eta_p^2 = .06$. The participants in the IR condition showed a 20ms increase in dwell time to the images overall while the participants in the II condition spent 3ms less on average looking at the images.

The critical analyses focus on the distribution of dwell time within the two AOI (the head attribute and interior attribute) across the conditions and blocks. See Figure 5 for the overall results. There was no main effect of the condition, $F(1, 62) = 0.05$, $p = .82$, $\eta_p^2 = .001$, but there was a main effect of the block as participants looked longer within the AOI during the second block of same-different trials, $F(1, 62) = 21.51$, $p < .001$, $\eta_p^2 = .26$. As in Exp. 1, participants looked longer within the interior AOI in general, $F(1, 62) = 128.64$, $p < .001$, $\eta_p^2 = .68$. Both the block by condition and attribute by condition interactions were not significant. However, there was a block by attribute interaction, $F(1, 62) = 20.06$, $p < .001$, $\eta_p^2 = .24$. Both conditions increased their looking time within the head AOI from block one to block two, but there was not increase in dwell time for the interior AOI. Unlike Exp. 1, there was no three-way interaction present, $F(1, 62) = 0.02$, $p = .90$, $\eta_p^2 = .00$. The conditions were similar in how their looking time patterns to the AOI shifted between the blocks of the same-different task.

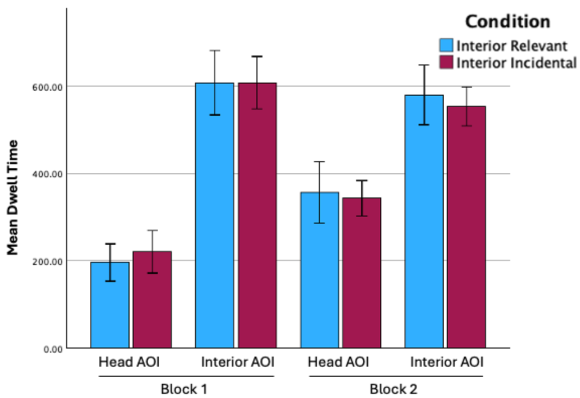


Figure 3: Dwell time averages from Exp. 2

## General Discussion

The purpose of this study was to gain more information about the relationship between selective attention as measured by eye-tracking methodology and the category knowledge acquired through goal-directed tasks. Prior research using this set of tasks had shown that participants readily learned to organize the items into coherent categories reflecting the goal-directed tasks (Chin-Parker et al., 2025). Here we examined how that knowledge relates to eye gaze patterns.

As expected, in Exp. 1 the goal relevance of the attribute, whether it was goal-relevant or goal-irrelevant, impacted the participants' attention to those attributes in the second block of the same-different trials. When an attribute was critical to the completion of the goal-directed task, participants spent more time looking at that attribute in the same-different trials even though there was no direct benefit for doing so during the same-different task. This result would seem to support the idea that participants recognized the goal-relevant attributes to be more informative, so they were attended to more in the second block of the same-different trials. However, in Exp. 2, the eye-tracking measures did not differentiate between the goal-relevant and goal-incidental attributes. If the alteration to the looking times in Exp. 1 was due to how participants had represented the different attributes of the items, there should have been some differentiation between the goal-relevant and goal-incidental attributes as was found in prior work examining goal-directed concept acquisition (Chin-Parker & Birdwhistell, 2017; Chin-Parker et al., 2025). The fact that the relationship between the goal relevance and attentional allocation held when comparing goal-relevant and goal-irrelevant attributes, but not goal-relevant and goal-incidental attributes, requires some reflection on what the eye-gaze patterns reveal.

The assumption that there is a tight linkage between selective attention and category knowledge is best captured by the idea that top-down factors, e.g. prior knowledge about the items, affect attentional allocation. In our study, top-down influences would occur because participants learned to recognize different categories of items based on the goal-directed task they completed. However, there are other factors that play a role in attentional allocation. We noted prior that the salience of the interior of the keys, a bottom-up factor, impacted the gaze patterns. Another factor is selection history (Theeuwes, 2019). Simply by having to look to the goal-relevant attribute (but not the goal-irrelevant attribute) during the goal-directed task could have been sufficient to drive the transfer to the second block of the same-different task in Exp. 1. That could also explain the lack of difference between the goal-incidental and goal-relevant attributes. In Exp. 2, participants had to allocate attention to both types of attributes to complete the tasks. So, even though the goal-relevant attribute may have been more central to the category knowledge, the attributes were equivalent in terms of the selection history. Across the two experiments, the selection history appears to explain the shifts, or lack thereof, in looking time from the first block of the same-different trials to the second block. However, selection history reflects the past allocation of attention of attention as opposed to underlying category knowledge associated with the items being attended to. The assumption that eye-gaze patterns reflect the conceptual knowledge is challenged by this insight. In studies using an eye-tracking methodology to study category learning, the notion of selection history has not been adequately addressed.

It is important to consider how we conceptualize attention in these studies. The construct of attention is multi-faceted (Chun et al., 2011), but thus far, I have used the term "attention" to refer primarily to the notion of spatial attention as this is the notion of attention most often invoked in eye-tracking studies of category learning. Attention is also implicated in processing that occurs to the information once it has been attended to. I propose that allocating spatial attention is sufficient to drive some learning, but it is not equivalent to the processing that occurs when the information about the attribute is critical to goal-directed actions. When the participant looked to the goal-incidental attribute, that could simply reflect selection history. However, when looking at a goal-relevant attribute there was likely additional processing associated with how that attribute had been implicated in the goal-directed task. The dissociation between the eye-tracking results reported in this study and the prior work examining goal-directed concept acquisition illustrate that difference.

The use of eye-tracking methodologies to inform our understanding category learning has led to useful insights, but to move forward we need more study across different situations to better understand the processes and representations involved.

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