Task Goals Structure Conceptual Acquisition

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Abstract

The purpose of this study is to explore the role goals play in concept acquisition. Goals motivate and shape our interactions with items, so it stands to reason that they also impact the learning that occurs as a result of those interactions. There is abundant evidence that goals orient us to particular information about the items we encounter. A more speculative claim is that goals play a more integral role in the acquired concept in that they also help to structure and cohere the acquired conceptual knowledge. Using a novel concept learning paradigm, we examined participant knowledge of attributes of the items they interacted with in an experimental task. We found evidence that the interaction of the goal with the learning situation impacted the centrality of the attribute information within their conceptual knowledge. These results support the idea that conceptual knowledge is organized in terms of goals active during learning.

Keywords: categories; concepts; goals; conceptual acquisition

Conceptual knowledge plays an important role in human cognition. Concepts help to shape our perceptions and predictions as we move through the world, and they allow access to information about entities that are not immediately present. All facets of cognitive science (e.g. philosophy, psychology, computer science, anthropology) have engaged with questions concerning conceptual knowledge, but important questions remain. This study focuses specifically on the ways that goal-directed interactions with instances from a novel category of items shape the organization and content of the acquired conceptual knowledge.

Within the psychological research, there has been on-going study of concept acquisition for over a century. Machery (2007) notes that despite significant shifts in the theoretical perspectives as to what constitutes conceptual knowledge, there has been a noticeable lack of variation in how psychologists operationalize the acquisition of a concept. Related concerns have been raised about category learning research in that the experimental paradigms are limited and potentially restrict our understanding of the processes involved in concept acquisition and how they affect acquired knowledge (Markman & Ross, 2003; Ross, Chin-Parker, & Diaz, 2005). There are also questions as to how well those experimental paradigms reflect concept acquisition as it happens in everyday life (Murphy, 2005).

In response to these concerns, there have been intentional and systematic attempts to broaden the range of learning tasks in the study of concept acquisition. The rationale is that examining learning that occurs in the course of different kinds of interactions provides a richer and more applicable sense of what conceptual acquisition is really like. Out of this, a line of research has emerged that examines how the goal of the learner affects concept acquisition. If an individual interacts with a set of items in the course of working towards a particular goal, the conceptual knowledge acquired from those interactions should be tuned such that it supports that goal (Chin-Parker & Birdwhistell, 2017; Jee & Wiley, 2007; Love, 2005). The idea that goals meaningfully intersect with conceptual acquisition has existed in the literature for several decades (see Barsalou, 1995), but only relatively recently has it been formalized within concept acquisition studies.

A basic assumption of this approach is that the goal points the individual towards features of the items that are goal relevant. Jee and Wiley (2007) and Chin-Parker and Birdwhistell (2017) have found strong evidence for this *goal-orientation hypothesis*. When participants with different goals interact with same set of items, the conceptual knowledge acquired privileges access to the attributes of the items that were critical to completion of the goal. This idea fits well with learning theories that incorporate some means for the learner to adapt to the differential importance or salience of individual attributes (e.g. Kruschke, 2003; Le Pelley, et al., 2016).

It has been suggested that goals also play a role in the representation of conceptual knowledge. Because a concept provides information as to why the instances of the corresponding category belong together, Jee and Wiley (2007) propose that the goal acts as a glue that coheres the members of the category. This idea reflects earlier work on ad hoc categories (e.g. Barsalou, 1983).

Chin-Parker and Birdwhistell (2017) provide an account that focuses on how a goal plays a role in organizing the attribute information represented within the concept. They note that in any situation there are many possibilities as to how an individual might interact with the entities that constitute that context. However, having a specific goal means that each possible interaction within that situation can be defined in terms of its goal-relevance. An interaction that moves the individual closer to, or further from, the goal can be considered goal relevant. An interaction that does not do so would not be goal relevant. If a goal-relevant interaction involves a particular facet of the item at hand, that aspect of the item becomes defined in terms of how it relates to the goal – the way in which it facilitates (or hinders) movement towards the goal. In this view, the attributes themselves become available through the interplay between what constitutes the items and the goal-directed behaviors. It is important to remember that these interactions are situated – what constitutes a goal relevant attribute and how that attribute relates to the goal may vary across situations. Through the goal-directed interactions, a structure emerges that reflects the goal-relevance of the various components of the situation – attributes that are more critical to completing the goal become more central within the concept. For instance, if an attribute was differentiated in relation to the goal, e.g. it offered a goal-relevant decision point, then the information about its differentiation with regards to the goal would also be captured within the acquired conceptual knowledge. The *goal-framework hypothesis* proposes that the goal is more integrated into the conceptual knowledge than is implied by the goal-orientation hypothesis.

The purpose of this study is to assess the goal-framework hypothesis. Participants interacted with a set of novel items in order to complete a particular task. These items represented two different types, although the participants were not told this: They were not asked to learn about the items or to do any explicit category-based work, only to use them to complete the task at hand. In both conditions the items had two primary attributes that were goal-relevant – the participant had to attend to both attributes to complete the task. However, we manipulated the task so the relationship of one of the attributes to the goal differed across conditions. We modified whether the specific shape of that attribute was *relevant*, i.e. that shape required a decision to made about how to proceed in the task, or if it was *irrelevant*, the interaction with that attribute occurred without any consideration of its specific shape.

Because the task required the participants to differentiate between the two types of items, we expected them to naturally recognize the two categories of items. We expected all participants should be able to assess class membership of the items based on the primary attributes and to make judgments based on those categorizations. Critically, we expected that our manipulation of the relevance of the shape of one of the attributes would affect later category-based judgments indicating that it had impacted the centrality of that attribute within the conceptual knowledge.

Experiment

Methods

Participants and Design Sixty-seven participants were randomly assigned to two experimental conditions: 33 participants were assigned to the *interior shape relevant condition* (ISR condition), and 34 to the *interior shape irrelevant condition* (ISI condition). All participants used

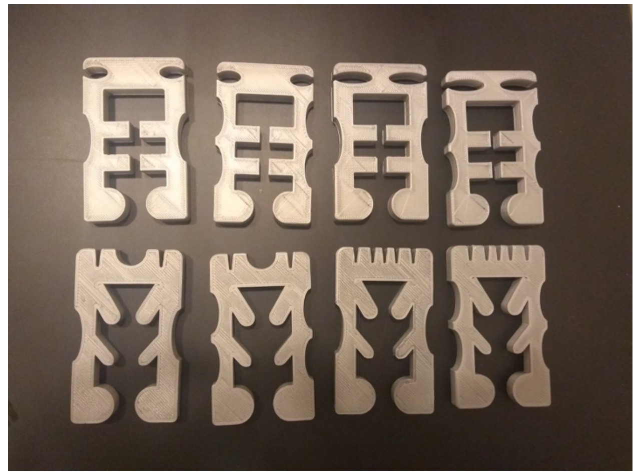

Figure 1: Keys used in the initial task. They were identified in the classification task as "alpha keys" (top row) and "zeta keys" (bottom row).

the same set of items during the initial task and completed the same transfer tasks. The presentation order of items during the initial and transfer tasks was randomized.

Materials and Procedure During the *initial task* of the experiment, all participants interacted with the same set of eight "keys" (see *Figure 1*). The keys had two primary attributes – the head shape and interior shape. These attributes co-varied so that there were two categories, or types, of keys defined by a particular combination of head and interior shape. The keys were made of ABS plastic and were created using a 3D printer. The keys were approximately 10 cm by 6 cm by 1 cm in size.

Participants used the keys to manipulate the task boards (see *Figure 2*). The boards were designed so the keys would be used as part of a two-step task. Each board featured a metal transport that could slide along the top surface of the board. The transport had an acrylic window that revealed a button the participant was instructed to press in order to complete the task.

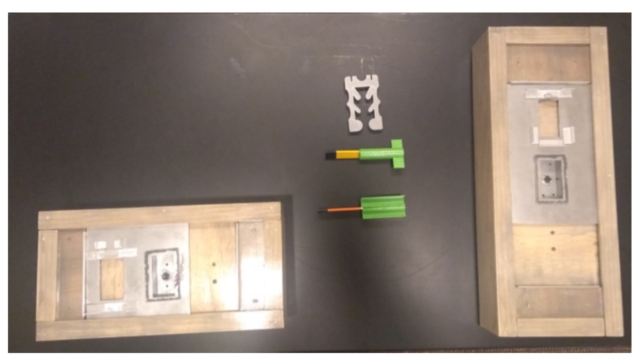

Figure 2: Set up of the initial task from the participant's perspective. The participant set the key onto the appropriate task board, slid the transport to reveal a button, then used one of the tools provided to press the button. The tools shown here were used in the ISR condition.

Figure 3: Close up of a "zeta" key placed on a task board. The shape of the key head (vertical slots on the top of the key) allowed it to fit onto the board (an "alpha" key with horizontal slots would not fit on this board). Here, the transport has been moved to its target position, so the button is accessible. To complete the second part of the task, a tool had to be inserted through the interior of the key to press the button.

The key frame on the transport was configured so that only one of the head shapes of the keys would fit into the frame for each board. Once a key had been properly placed into the frame, the transport could be moved to the target position (see *Figure 3*). This constituted the first part of the participant's task. When the transport was moved into the target position, the participant had access to the button through the interior of the key. The participant was instructed to press the button using a tool provided for that purpose (see *Figure 4*). Using one of the tools to press the button constituted the second part of the task. Once the participant pressed the button, lights built into the board turned on signaling that the task had been successfully completed.

As noted, the first part of the task required the participant to attend to and differentiate the head shape of the key being used so that the key could be correctly placed onto one of the task board transport frames. The second part of the task required the participant to attend to the interior shape of the key. In the ISI condition, the interior shape of the key was irrelevant in terms of which tool could be used. Participants in that condition could select either of the two tools available to press the button. In the ISR condition, the tools were designed so that each tool fit with the interior shape of one of the types of keys (either the alpha keys or zeta keys). Participants in that condition not only had to attend to the interior, they had to make a decision about which tool to use given the interior shape of the key.

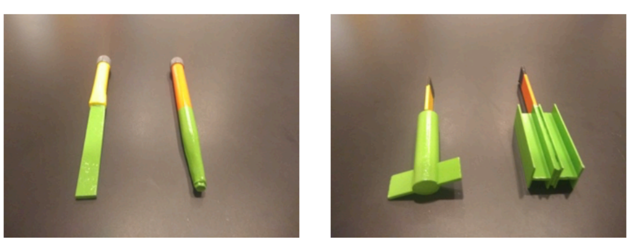

Figure 4: In the ISI condition (tools on left), either tool could be used with any key. In the ISR condition (tools on right), the tool used depended on the interior shape of the key.

At the start of the experiment, participants were introduced to the keys, task boards, and tools with a set of practice materials that allowed them to familiarize themselves with the basic aspects of the task (i.e. place a key onto the transport of one of the boards, move the transport, use a tool to press the button). However, the practice keys had different shape attributes and fit onto the transports differently (and the transports rotated on the surface of the board instead of sliding). Once the participant indicated they were comfortable with the basic idea of the task, the practice materials were replaced with the actual task boards and tools for the study. It is important to note that at no time during the initial task trials were the participants told that there were different types of keys – each trial featured one key and the instructions and communication with the participant focused solely on the completion of the task.

At the start of each trial during the initial task, the experimenter set a key (determined by a randomized order for each participant) on the table between the task boards. As described prior, the participant's task consisted of placing the key onto the proper transport, sliding the transport to its target condition, and then pressing the button using one of the tools. The participant handed the key back to the experimenter, the transport on the task board was returned to its initial position, and the trial ended. The keys were kept out of sight except for when they were being used during a trial. The participant completed two blocks of eight trials during the initial task. Each key was used once within each block.

After the initial task trials, the participants moved to a computer workstation. The computer tasks were designed and administered using PsychoPy software (Peirce, 2007). The images of the keys used in the computer tasks were created using the same computer aided design (CAD) software that was used in printing the physical keys. The 3D images of the keys used during the following tasks were identical to the physical keys the participants had used during the initial tasks, excepting for the modifications noted below.

The first task the participant completed on the computer was a *classification task*. The purpose of this task was to provide the participants with labels for the concepts they had acquired during their initial interactions with the keys. Chin-Parker and Birdwhistell (2017) showed that participants can make category-based judgments, e.g. sorting and similarity judgments, following goal-directed tasks even without explicit labels, but as we planned to use a category-goodness rating task, the participants needed a way to explicitly differentiate the concepts. Because the general head and interior shape were perfectly correlated in the keys, the participants could use either, or both, of those attributes to guide their classification decisions. We expected the participants to look to whichever feature they already considered to be critical in terms of their knowledge of the keys, so the classification task should only reinforce the concepts they acquired during the initial task.

The initial screen of the classification task provided information about the task, and at this point the participants were explicitly told that there were two types of keys, identified for the classification task as “alpha keys” and “zeta keys”. During each trial of the classification task, the image of a key was presented and the participant used the mouse to indicate whether they thought it was an alpha or zeta key. The participant received feedback on her classification, and the correct label for the key was shown with the key so that she could study it for two seconds before the next trial began. Each participant completed 16 classification trials comprised of two blocks of the eight keys used in the initial task.

After completing the classification task, the participant began the *category rating task*. Each trial consisted of an image of a key presented with a category label (see *Figure 5*). The participant was instructed to rate how good a member of the indicated category the key was. The participant could use the mouse to click on a rating scale that went from 0 (labeled with “definitely not this type of key”) to 100 (labeled with “perfect example of this type of key”). The participant was encouraged to use the entire range of the scale in order to most accurately reflect her ratings of the keys shown.

Each participant completed 32 trials in the category rating task. There were eight types of items shown during

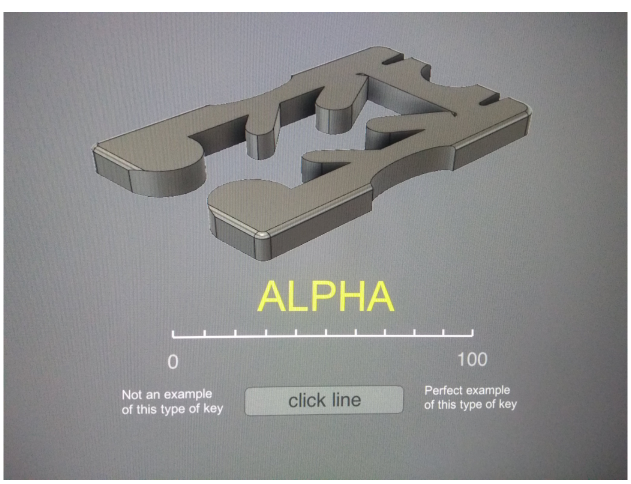

Figure 5: Screenshot of an Old Mismatch trial of the category rating task.

the task, four instances of each type. They were balanced in terms of whether they represented alpha or zeta keys. In the *old match trials*, the key shown was one from the initial task and it was displayed with the correct category label. In the *old mismatch trials*, a key from the initial task was displayed with the incorrect category label. In the *new match trials*, new versions of keys that matched the keys from the initial task (and these keys would have functioned the same with the task boards and tools) were displayed with the appropriate label. In the *head violation trials*, the image of the key was modified so that it had the same basic shape, but it would no longer fit onto either key frame if it had been used in the initial task. In the *interior violation trials*, the interior of the key was modified so that it had a different shape that would keep any tool (from either the ISI or ISR conditions) from being able to reach the button in the initial task. The *head/interior mismatch* trials had items where the head from one type of key was matched with the interior from the other type of key, and these keys were presented with the label that matched the head of the key. Finally, there were *minor match trials* and *minor mismatch trials* where superficial aspects of the keys (e.g. whether the edges were rounded or squared off) were modified, and the key was presented with either the correct or incorrect label. These items were considered filler items.

After the participant completed the category rating task, she was asked to move back to the task table. The task boards had been removed, and a pile of 16 “miniature” keys were in the center of the table. These keys were printed at ¼ scale and matched the keys from the initial task in terms of their attributes. Eight of these keys were identical to the initial task keys. The other eight keys were like the head/interior mismatch items from the category rating task – the head of one type of key was paired with the interior from the other type of key. The experimenter instructed the participant to “put these keys into groups that you think naturally reflect the types of keys you worked with today.” The participant was free to sort the keys into any number of groups. Once the participant indicated she had completed the sorting task, the experimenter asked her to explain the sort.

Results

Initial Task Participants in the ISR condition (M = 221.03 secs, SD = 96.46) took longer to complete the first block of trials of the initial task than participants in the ISI condition (M = 162.24 secs, SD = 43.06), $t(65) = 3.24$, $p = .002$, $r_{pb}^2 = 0.14$. The difference persisted into the second block, but was much smaller in magnitude: ISR condition (M = 118.15 secs, SD = 21.59), ISI condition (M = 106.09 secs, SD = 19.82), $t(65) = 2.38$, $p = .02$, $r_{pb}^2 = 0.09$.

Classification Task There were no differences in the participants’ ability to complete the classification task. The mean accuracy for the ISI condition (M = 0.95, SD = 0.07) was nearly identical to the ISR condition (M = 0.96, SD = 0.07), $t(62) = 0.27$, $p = .78$, $r_{pb}^2 = 0.001$.

Category Rating Task The initial analysis of the category goodness ratings (see *Table 1*) was an omnibus test to determine whether the ISI and ISR conditions showed different patterns of ratings across the items. The category ratings were analyzed using a 2 (condition) X 8 (item type) mixed ANOVA. There was no main effect of the condition, $F(1, 65) = 0.07$, $p = .80$, $\eta_p^2 = .001$, but there was a significant main effect of the item type, $F(7, 455) = 78.04$, $p < .001$, $\eta_p^2 = .55$. Critically, there was a significant interaction between the condition and item type, $F(7, 455) = 2.16$, $p = .04$, $\eta_p^2 = .03$. Looking at the overall results, participants in both conditions provided similar ratings when both the head and interior of the key indicated the same category (i.e. the old match, new match, old mismatch, minor match, and minor mismatch items). The interaction appears to arise from a differential rating across items where the head and interior provided different information about the category membership.

Table 1: Mean Category Goodness Ratings (and Std. Error) Organized by Item and Condition

	Initial Task Condition	
Item	Interior Shape Irrelevant (ISI)	Interior Shape Relevant (ISR)
Old Match	85.13 (2.81)	85.52 (2.85)
New Match	73.10 (3.28)	77.61 (3.33)
Old Mismatch	10.33 (2.77)	13.77 (2.81)
Head Violation	40.38 (5.18)	50.27 (5.26)
Interior Violation	50.80 (5.87)	34.71 (5.96)
Head/Interior Mismatch	55.16 (6.47)	42.52 (6.57)
Minor Match	75.25 (3.81)	75.50 (3.86)
Minor Mismatch	13.57 (3.18)	13.82 (3.23)

As noted, we expected the manipulation of the relevance of the interior shape would affect the centrality of that attribute within the conceptual knowledge. To test this idea, we ran a more focused set of ANOVAs that assessed the conditions in terms of their ratings for the old items (as a baseline for the category ratings) compared to the items where the head and interior attributes provided different information about the category membership of the key (head violation, interior violation, and head/interior mismatch items). Across the analyses, there was a consistent effect of the item types (all ps < .001) because the old items were reliably rated as better members of the target categories compared to the items that contained inconsistent attributes. There was also no main effect of the condition in any of the analyses (all ps > .10). However, the interaction terms differed across the analyses. For the head violation items, $F(1, 65) = 1.19$, $p = .28$, $\eta_p^2 = .02$, and head/interior mismatch items, $F(1, 65) = 2.08$, $p = .15$, $\eta_p^2 = .03$, there was no interaction between the condition and item type. For the interior violation items, there was a significant interaction between the condition and item type, $F(1, 65) = 4.27$, $p = .04$, $\eta_p^2 = .06$. The interaction in the primary analysis appears to have occurred because the participants in the ISR condition dropped their ratings for the interior violation items in comparison to the old items more than the participants in the ISI condition did.

Sorting Task The participants in both groups created a variety of sorts for the miniature keys, and these sorts varied in terms of whether they reflected attention to a single attribute or multiple attributes. The sort by one participant in the ISR condition was not based on the physical attributes of the keys, so her data were removed from these analyses.

There was no difference in the number of groups created by participants in each condition (ISI condition: $m = 3.35$, $s = 2.28$; ISR condition: $m = 3.28$, $s = 1.99$), $t(64) = 0.13$, $p = .89$, $r_{pb}^2 = 0.001$. The proportion of participants that used information about the head of the keys (77% of ISI; 53% of ISR) differed between the conditions, $X^2_{(1, 64)} = 3.96$, $p = .04$, $v_c^2 = .06$. However, the proportion of participants that used information about the interior of the keys (53% of ISI; 66% of ISR) did not differ between the conditions, $X^2_{(1, 64)} = 1.10$, $p = .30$, $v_c^2 = .02$.

Forty-two participants (24 in the ISI condition, 18 in the ISR condition) sorted the items into only two groups. Those sorts provide a direct insight into what aspect of the keys was considered critical because the sort was based on a single attribute. Of this subset of participants, 66% of the participants in the ISI condition sorted the keys based on the head of the keys while 66% of the participants in the ISR condition sorted based on the interior. The primary attribute for the sort differed between the conditions, $X^2_{(1, 42)} = 4.58$, $p = .03$, $v_c^2 = .11$.

Discussion

The results of this study provide additional evidence for the goal-framework hypothesis. The participants in the two conditions were given equivalent tasks (and thus equivalent goals) to guide their interactions with the keys. In both conditions, the goals associated with their tasks oriented them to both of the critical attributes of the keys: the shape of the head and the shape of the interior. If the goal orientation hypothesis were sufficient to account for the role of the goal construct in the learning, the two conditions should have been largely equivalent in terms of how they organized their knowledge of the critical features of the keys. In some ways, they did show comparable learning. There is a striking similarity in terms of how the participants rated many of the items regardless of condition. For instance, the mean ratings for the old match, new match, old mismatch, minor match, and minor mismatch items are nearly identical across the conditions. In all of those items, the head and interior attributes of the keys were in agreement with regard to the type of key shown. However, when the attribute information conflicted, the ratings differed between the conditions.

The participants in the ISI condition tended to consider the head shape as more critical when judging the category goodness of the items. Their ratings for the head violation items is lower than their ratings for the interior violation items. They also had a tendency to use the shape of the head of the key more consistently when organizing the keys during the final sorting task. The participants in the ISR condition tended to consider the interior of the keys as more critical to the category goodness, and they used the interior shape more consistently when sorting the keys.

As expected, the participants in the ISI condition acquired and used some knowledge of the interior shape in the category-based tasks. As noted, having to pay attention to the interior shape is sufficient to drive some learning. However, we would argue that their knowledge of the interior shape was less central to their concept of the key compared to the ISR condition, so it did not affect their ratings as much. A potentially important contribution of the notion of the goal-framework is that it explicitly connects the experiences of an individual, their interactions with objects in the world, to their conceptual knowledge.

It is not clear why the ISR participants showed less sensitivity to the head shape than the ISI participants. The head attribute played a comparable role in the task completion for both conditions. It is possible that having two goal-relevant attribute distinctions required some weighting of those attributes within the concept. This would fit with models of conceptual acquisition that have such a mechanism in place to account for the differential learning of attribute information. As suggested by an astute reviewer, it is also possible that the proximity of that part of the task to the completion of the goal might have privileged the knowledge of the interior shape in the concept. However, further study is necessary to determine why the ISR participants tended to emphasize the interior shape over the head shape.

The critical difference between the conditions was in the role the interior shape played in terms of how the participant could reach the goal. Both conditions had the same goal, to press the button, but the different tools during the second part of the task meant that the interior shape played a qualitatively different role in achieving that goal. In the ISI condition, the participant had to attend to the interior shape of the key in order to navigate the tool and press the button, but the shape of the interior of the key did not have relevance to the task beyond that. In the ISR condition, the shape of the interior was critical to differentiating the use of the tools to press the button. In this way, the differentiation of the shape of the interior was relevant to completing the task.

Chin-Parker and Birdwhistell (2017) posit that the learning process involves the development of the "goal framework" and that this framework reflects the structure that emerges as an individual interacts within a particular situation with a certain goal. In this way, the framework organizes the incoming information in terms of its goal-relevance providing structure to the acquired knowledge. They also propose that this framework is involved in organizing aspects of the basic perceptual experience of the individual when operating in a novel domain because there has to be some means to constrain the development of a feature language (see Landy & Goldstone, 2005). Although the current study was not designed to test these aspects of the goal-framework hypothesis, they fit within the experiences of the participants. When they had arrived for the study, they had no idea what the keys were or how to think about them. By the time they had completed the sorting task, they had a meaningful sense of what the keys were. As we develop this paradigm, we intend to revise the tasks so that we have the power to look at subtler indicators of the developing conceptual knowledge so we can assess these other claims.

This study examines concept acquisition in an arguably more naturalistic manner than most research in this this area. Our participants used the keys to complete an admittedly simple and arbitrary task, but in doing so, they had meaningful interactions with objects in a particular context in order to reach a goal. As a result, they developed useful ways to organize their knowledge of keys. This kind of experience invokes pragmatic constraints that are important to conceptual acquisition (Barsalou, 2017). The concept acquisition that occurs is not driven solely by the physical characteristics of the keys. Similarly, the goal of individual, in isolation, is unable to account for the conceptual acquisition. Instead, it is the interactions between the individual and environment that allow the useful structure to emerge.

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