Knowing when to quit:
Children consider access to solutions when deciding whether to persist

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Abstract

Although persistence is essential to overcoming challenges and making new discoveries, continued effort can be costly. Even very young learners must make decisions about when to invest effort and when to abandon a task. In the current study, we explore whether children's decisions about when to exert effort are influenced by the information they stand to gain in a particular learning situation. That is, we examine whether providing children with solutions after they attempt to complete a challenging task reduces their persistence. Sixty 4- and 5-year-old children completed a series of iSpy puzzles and then attempted to activate a novel toy. Children were either presented with the solutions after attempting each task or given no information about the answers. Our results demonstrate that children persisted longer at attempting to activate a novel toy when their effort was more likely to be the only source of information: children who expected to be provided with the solution gave up faster than those who did not. We discuss the implications of these findings on children's rational decisions about when effort is worthwhile, and consider how providing answers might impact motivation and curiosity more broadly.

Keywords: persistence, exploration, information gain, answers

Introduction

Persistence in childhood has repeatedly been associated with positives outcomes: Persistence at 6 months predicts cognitive development at 14 months (Banerjee & Tamis-LeMonda, 2007), perseverance at 3 years predicts language and math skills in kindergarten (Mokrova, O'Brien, Calkins, Leerkes, & Marcovitch, 2013), and persistence in childhood predicts later academic achievement (Meier & Albrecht, 2003), success at work, and healthy relationships (Duckworth, Peterson, Matthews, & Kelly, 2007; Eskreis-Winkler, Duckworth, Shulman, & Beal, 2014).

While it is clear that some amount of persistent effort is required to master difficult material and develop new skills, it is equally important for a learner to recognize *when* to exert high effort. Learners must continuously make decisions about which challenges to confront, and which to abandon (Lucca, Horton & Sommerville, 2020). This decision-making process is particularly salient during exploration, as a novice learner (by definition) does not know exactly how much effort will lead to reward, or whether prolonged effort will allow them to discover anything informative at all.

Indeed, recent work has provided evidence that young children consider costs and rewards when making decisions: 18-month-olds weigh the expected costs and benefits of their actions when deciding whether to help an adult construct a tower composed of blocks of different weights (Sommerville et al., 2018) and preschool-aged children tailor their teaching by maximizing learners' rewards and minimizing costs in a causal learning task (Bridgers, Jara-Ettinger, & Gweon, 2019; Gweon & Schulz, 2019).

Deciding when to persist likely recruits a similar analytic process, since it is essential for learners to consider whether persisting will maximize learning and discovery, or whether the anticipated reward does not actually outweigh the cost of exploration (Lucca & Somerville, 2018). After all, if learners persist for too long on a difficult task, they may lose the opportunity to spend time and effort on an achievable and rewarding alternative (Lucas, Gratch, Cheng, & Marsella, 2015).

One factor that influences even very young children's decisions about when to persist and when to 'give up' is the behavior of the adults in their environment (Kamins & Dweck, 1999; Lucca, Horton, & Sommerville, 2019). For example, Leonard, Lee and Schulz (2017) demonstrated that infants tend to make generalizations about when to persist based on adult behavior. When 15-month-olds observed an adult work hard to achieve a particular goal (e.g. trying different strategies, repeating actions), they themselves attempted to activate a novel toy more times than infants who observed an adult succeed after little to no effort. Observing adults exert effort also increases persistence in preschool-aged children, although this effect only occurs when the adult's effort actually leads to success (Leonard, Garcia, & Schulz, 2019). Based on these findings, the authors argue that children reason rationally about observed effort, only generalizing the benefits of persistence when adults succeed. In other words, children infer that the cost of effort is worthwhile when it is instrumental to achieving a particular goal. When adult persistence leads to failure, children reason that effort is not likely to lead to a reward. In line with this account, children also use the behavior modeled by adults to infer when a task may be too difficult for them to succeed on their own. For example, children persist less when their parents (or other adults) take over during a challenging task, compared to instances when adults provide direct instruction or no input at all (Leonard, Martinez, Dashineau, Park, & Mackey, 2019, preprint).

A related literature has shown that children's perseverance and exploration is also sensitive to more explicit pedagogical cues. For example, asking children "pedagogical questions"—i.e. asking questions with the intention to teach, rather than to receive a specific answer—leads preschool-aged children to explore more and persist longer, when attempting to activate a novel machine (Jean, Daubert, Yu, Shafto, & Bonawitz, 2019; Yu, Landrum, Bonawitz, & Shafto, 2018). Direct instruction can also influence exploration and persistence. For example, children show reduced exploration of a novel toy following a pedagogical demonstration of one of the toy's features (Bonawitz et al., 2011). Computational work explaining these effects suggest that when learners receive direct instruction, they make assumptions about the amount of information that remains to be learned (Bass, Shafto & Bonawitz, 2018; Shafto, Goodman & Griffiths, 2014). As a result, learners rationally adjust their exploration in response to particular teaching styles or examples. For instance, six-year-old children explore more when they believe a teacher will be under-informative, relative to a knowledgeable teacher (Gweon, Pelton, Konopka, & Schulz, 2014).

In the absence of guidance from adults or pedagogical instruction, the opportunity to gain specific types of information has, in itself, also been found to motivate children to persist. For example, Alvarez & Booth (2014) found that receiving causally rich information about novel visual stimuli (e.g. an explanation of how an object is used to achieve a goal) as a reward after completing an unrelated, uninteresting task (i.e., repeatedly placing pegs in a board) can motivate 3- to 5-year-old children to persist longer on that task compared to receiving causally weak information (e.g. a description of the object), or no information at all. While this research demonstrates that a specific type of information (i.e. causally rich information) can increase motivation, gaining *any* relevant information can also be rewarding. Specifically, Schulz, Pelz, Gopnik and Ruggeri (2019, preprint) presented children with a game in which they had to search for an animal behind an unspecified number of doors. In one condition, children were told which animal they were searching for, and would therefore gain no new information upon finding the animal. In a separate condition, children were told that the animal would be one of a set of eight, allowing them to gain information about *which* animal was hidden if they found it. Children who did not know what animal they were looking for searched longer than children in the known animal condition, demonstrating that children's search can be motivated by information gain alone.

Here, we examine whether children's persistence is sensitive to the amount of information available in the learning environment, in the absence of adult models or explicit pedagogical cues. That is, we consider whether children's persistence in an exploration task is affected by the apparent *accessibility* of information. Past work with adults has shown that simply viewing the solutions to a problem after attempting to solve it (e.g. solving anagrams) can decrease the amount of time they spend searching for solutions on subsequent problems (Risko et al., 2017). To examine the effect of providing answers on children's persistence, we manipulate whether children expect that they will be provided with solutions after attempting a series of challenging tasks. We then examine whether this expectation influences their behavior on a subsequent, (unrelated) task in which they are invited to explore a novel causal toy. We operationalize persistence in the context of exploratory learning in two ways: (1) the overall time children spend exploring the toy and (2) the number and type of actions performed. Measuring overall time provides a broad measure of persistence, capturing any effort, while examining the unique actions taken reveals whether children attempt a wider variety of strategies based on the information they expect to gain.

This approach is distinct from past work on persistence in a couple of ways. First, children are not given the opportunity to observe an adult engage in any effortful behavior, nor are they shown pedagogical demonstrations that might influence their own behavior. In other words, children in the present study cannot make inferences based on previous observations about the value of sustained effort or whether any information remains to be learned. Instead, the only aspect of the learning environment that is available to them is the information they stand to gain as a result of their own sustained effort. In addition, unlike in previous work in which an adult interrupted children's efforts (Leonard et al., 2019b), participants in the present study will be told *in advance* that solutions will be provided and were never provided with explicit information about the difficulty of the task.

One reason to believe that simply making task solutions available will be sufficient to impact children's persistence is based on prior research suggesting that the decision to persist is affected by children's assessment of the cost and rewards associated with acting on a given problem (e.g., Sommerville et al., 2018). Further, this assessment is influenced by the learner's belief about how much information there is to gain (Bass et al., 2017; Schulz et al., preprint). In the current study, we therefore present two conditions that provide children with different opportunities for information gain. Specifically, in the *answers* condition, children can acquire complete information about how to activate a novel toy by giving up on the task and deferring to a knowledgeable adult. As a result, continued effort is rendered both inefficient and costly, with little added benefit in terms of information gain. In contrast, in the *no answers* condition, the only way for children to discover the causal structure of the novel toy is via their own sustained persistence. Thus, the present study examines whether an expectation that solutions will be provided undermines children's persistence on an exploratory learning task.

Method

Participants

A total of sixty 4- to 5-year-olds participated in the study, with 30 children randomly assigned to either the *answers* (M = 4.9 years, SD = .54, range: 4.01 – 5.98 years) or *no answers* (M = 5.0 years, SD = .56, range: 3.98 – 5.83 years) conditions. Sample size was preregistered and was based on similar studies that used children's play time as a dependent measure (e.g., Yu et al., 2018)[1]. Based on preregistered criteria, an additional 13 participants were excluded due to experimenter error (2), failure to complete all of the tasks in the study (2), parent or sibling interference (6), leaving the table part-way through the experiment (2) or for finding all of the objects in all of the iSpy games before the time ran out (1). Children were recruited and tested at preschools and local children's museums.

Materials

Three unique "iSpy" puzzles were used during the first phase of the study. Each puzzle contained an array of familiar objects (e.g., umbrellas, carrots, volcanos, etc.; see Fig. 1 for an example array), arranged in a random configuration. A one-minute sand timer was used while children engaged in the iSpy task. This was included so that children did not think the experimenter was ending the iSpy game prematurely.

A novel "toy" that was approximately 15" x 12" x 2" was also created (see Figure 2). The toy had a variety of affordances that children could act on: four identical small green buttons, two large buttons of different colors, and two different colored lights. Critically, none of the buttons actually activated the toy, which was in fact surreptitiously controlled by the experimenter using a remote. Thus, the toy was impossible for children to activate themselves. When the toy was "activated" by the experimenter (using a screen to block children's view of the causal demonstration) a short melody played.

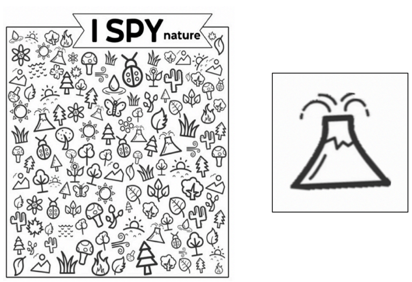

Figure 1. "iSpy" game presented to children. An 8.5 x 11" version of the array of objects (left) was given to children, accompanied by an image of the target object they were asked to search for (right).

Procedure

Children were tested individually in a quiet corner of the museum or preschool. The experimenter began the study with the iSpy game. This activity was included to establish a reliable expectation about whether the experimenter would provide children with answers or not in either condition. In both conditions, children were told they would have to find a

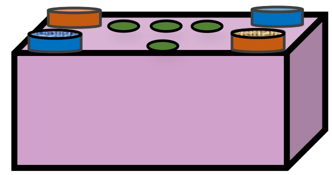

Figure 2. Schematic of novel toy presented during exploration phase.

unique target object in each "iSpy" picture, and that they would play the game three times with three different pictures. The order in which the iSpy pictures were presented was counterbalanced across participants. The one-minute sand timer was then introduced, so children knew exactly how much time they would have to find the target object in each picture. The experimenter explained that when all of the sand from the top of the timer reached the bottom, they would have to stop looking.

Children were then given each iSpy picture one at a time. The experimenter provided a cue card with an image of the target object on it (e.g. a volcano; see Figure 1) and told children how many of that object were in the picture (e.g., "In this picture you have to find all of the [volcanoes]. There are six [volcanoes] in this picture!").

In the *answers* condition, the experimenter then told children that they would "have to stop looking once the timer runs out, and then [the experimenter] will show you where all of the [volcanoes] are!" In the *no answers* condition children were told they would "have to stop looking once the timer runs out, and then [the experimenter] will put the picture away!" The experimenter then started the timer and allowed children to search for the target object for one minute. After the time ran out, children in the *answers* condition were shown the location of each of the target objects in the picture, while in the *no answers* condition the experimenter put the picture away and moved on to the next iSpy game.[2]

After children completed all three iSpy games, the experimenter introduced the novel toy. In both conditions, children were told that they could play with the toy for as long as they wanted. In the *answers* condition, children were additionally told: "When you're done playing with [the toy], I'll show you how to turn it on." In the *no answers* condition children were told: "When you're all done playing with [the toy] I'll put it away!"

Prior to allowing children in either condition to freely explore the toy, the experimenter demonstrated that the toy did in fact turn on (and was not broken). To do so, a screen blocking the child's view of the toy was placed on the table while the experimenter activated the toy behind the screen. After this demonstration, children were reminded that they could play with the toy for as long as they wanted.

[1]Link to preregistration: https://aspredicted.org/blind.php?x=2mr8ah. Note: At the time of preregistration, approximately 50% of the data had been collected, but data analysis had not begun, and the hypotheses, procedure and planned sample size were not changed.

[2] If children in the *answers* condition found all of the target objects in one of the pictures, the experimenter still indicated the location of each object to children prior to moving on to the next iSpy game. If this occurred in the *no answers* condition, the experimenter moved on to the next iSpy game.

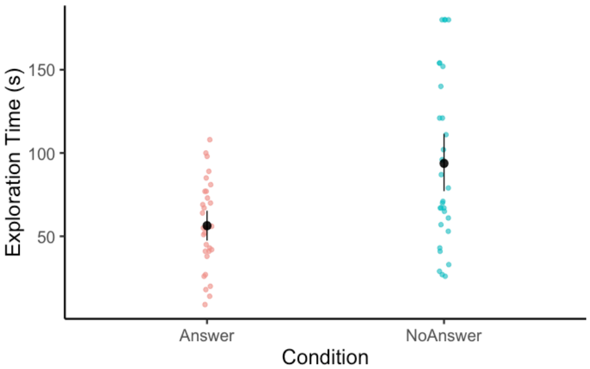

Figure 3. Time spent attempting to activate the novel toy in each condition. Error bars indicate bootstrapped 95% confidence intervals.

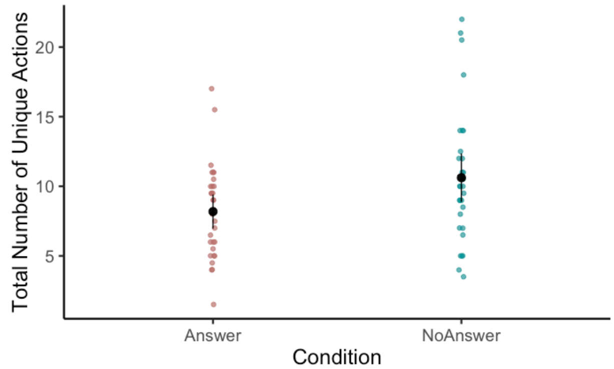

Figure 4. The total number of unique actions children performed in each condition when exploring the novel toy. Error bars indicate 95% CI.

The experimenter told children that they were going to do some paperwork and that the child could tell the experimenter when they were done playing. If children stopped playing with the toy for 10 consecutive seconds, indicating that they might quit, the experimenter prompted them by asking, "Are you all done or would you like to keep playing?" After three minutes, the experimenter ended the experiment for all children.

Results

Persistence was originally operationalized in two ways: the total time children spent trying to activate the novel toy and the number of unique actions children performed on the toy. Exploration time was calculated from the time when children first touched the toy and until the time of their last touch. Two individuals coded exploration time on all videos, with one blind to condition and the study hypothesis. Inter-rater reliability was $r > .98$.

Coding criteria for the number of unique actions children performed was preregistered and was recorded based on each unique action (i.e., if a single action was conducted multiple times, it was only counted once). For example, we recorded which buttons children pressed, whether children pressed unique combinations of two or more buttons, or if children acted on the entire toy (e.g. shaking the toy, lifting it in the air, looking underneath). The rationale for examining the number of unique actions was to explore whether some children simply exhausted more possibilities, regardless of the actual time spent. Examining exploratory behavior also reveals the number of different strategies children attempt while trying to reach their goal, which provides an additional measure of persistence.

Two individuals, both blind to condition and study hypothesis, coded the number of unique actions children tried during both the first minute of play and during the total play time. Seventy percent of the videos were coded by both coders, with an inter-rater reliability of $r > .84$. Any disagreements between coders were resolved by taking the average of the two coders' responses.

iSpy Performance

On average, children found 13.2 (of 19) objects across the three iSpy games (95% CI [12.4, 13.9]), with no difference between the *answers* ($M = 13.0$, 95% CI [11.0, 13.0]) and *no answers* ($M = 13.3$, 95% CI [12.3, 13.4]) conditions, $t(57.8) = -.489$, $p = .627$, $d = .13$. There was also no interaction between performance across time and condition ($p = .572$), such that children's performance on each trial did not vary as a function of condition.

Preregistered secondary analyses revealed that the number of objects that children found during the iSpy game did not have an impact on how long children attempted to activate the toy ($F < .001$, $p > .98$), or on the total number of unique actions children performed ($F(1, 56) = 1.92$, $p = .17$, $\eta_p^2 = .03$), with no condition interactions (ps > .5).

Exploration Time

The first major result of interest is the amount of time children spent attempting to activate the novel toy (Figure 3). An ANOVA revealed a main effect of condition, such that children in the *answers* condition spent less time playing with the novel toy ($M = 56.4$ s, 95% CI [46.9, 65.1]) than children in the *no answers* condition ($M = 93.8$ s, 95% CI [76.2, 112.2]), $F(1, 55) = 12.87$, $p < .001$, $\eta_p^2 = .19$, with no main effects of counterbalance ($F(2, 55) = 1.23$, $p = .301$, $\eta_p^2 = .04$) or age ($F(1, 55) = .003$, $p = .958$, $\eta_p^2 < .01$).

Number of Unique Actions

Next, we examined the number of unique actions that children performed on the toy during the total play time (Figure 4). An ANOVA revealed no main effect of condition, such that children in the *answers* condition performed marginally fewer unique actions ($M = 8.2$, 95% CI [7.0, 9.4]) than those in the *no answers* condition ($M = 10.3$, 95% CI [8.8, 11.8]), $F(1, 55) = 3.89$, $p = .054$, $\eta_p^2 = .07$, with no effect of counterbalance, $F(2, 55) = .558$, $p = .576$, $\eta_p^2 = .02$) or age, $F(1, 55) = .371$, $p = .545$, $\eta_p^2 < .01$). Examining just the number of unique actions children performed during the first minute of play showed a similar result, such that there was only a marginal difference in the number of unique actions children performed across conditions (*answers: M* = 8.4, 95% CI [7.0, 9.8]; *no answers: M* = 10.4, 95% CI [8.8, 12.1]; $F(1, 55) = 3.09$, $p = .084$, $\eta_p^2 = .05$), with no effect of counterbalance or age (*p*s > .56).

Unplanned Analyses

Given this marginal effect of the difference in the number of unique actions across conditions, we conducted additional unplanned analyses. First, since the lack of a significant difference may have been due to ceiling effects, we compared the *total* number of actions taken on the toy. We also analyzed the amount of time lapsed before children's first 10s pause in exploration (i.e., when children received their first prompt from the experimenter) as an additional measure of persistence. This rationale for this additional analysis was to examine whether children in the *answers* condition showed signs of giving up sooner than those in the *no answers* condition. Two individuals, blind to condition, coded these additional events (*r*s > .94). Any disagreements were resolved by taking the average of the two coders' responses.

Total Actions An ANOVA revealed a main effect of condition on the total number of actions that children performed, such that children in the *answers* condition tried fewer total actions ($M = 55.6$, 95% CI [41.6, 69.6]) than those in the *no answers* condition ($M = 87.5$, 95% CI [65.0, 110.0]), $F(1, 55) = 5.47$, $p = .023$, $\eta_p^2 = .09$, with no effect of counterbalance or age (*p*s > .39).

Time Until First Prompt An ANOVA revealed a main effect of condition on the time until the first prompt, such that children in the *answers* condition indeed paused sooner ($M =$ 53.8s, 95% CI [44.5, 63.1]) than those in the *no answers* condition ($M = 73.8$s, 95% CI [61.2, 86.4]), $F(1, 55) = 6.15$, $p = .016$, $\eta_p^2 = .10$, with no effect of counterbalance ($F(2, 55) = 1.39$, $p = .258$, $\eta_p^2 = .05$) or age ($F(1, 55) = .100$, $p = .753$, $\eta_p^2 < .01$). These results provide converging evidence for decreased persistence in the *answers* condition

Discussion

When encountering a novel learning problem, learners must decide when to persist and when to move on to something new. Here, we found that children's decisions about when to exert effort may be influenced by the information they stand to gain in a particular learning situation. In particular, when children expected to be provided with the solution after attempting to activate a novel toy themselves, they spent less time and took fewer actions to try to figure out how the toy worked than children who did not expect to receive the solution.

This demonstrates that children's persistence is sensitive to the availability of solutions, with easily accessible information potentially undermining children's tendency to apply more effort to a novel problem. That is, children persisted longer at attempting to activate a novel toy when their effort was more likely to be the only source of information. This behavior may reflect a rational inference about when to exert effort based on the information available, independent from adult testimony or modeled behavior (e.g. Leonard et al., 2019; Lucca et al., 2020).

Although we found a difference between conditions in the total time children spent exploring the novel toy, the amount of time prior to their first pause, and the total number of actions taken, there was only a marginal difference in the number of *unique* actions children performed. One possible explanation for this is the fact that the toy's affordances (i.e., buttons of different colors and shapes) were obvious to children following visual inspection. Beyond pushing each button individually, the only additional actions available to children were unique combinations of one or more buttons. However, discovering a causal rule of this type is challenging and not intuitive for young children (Bridgers et al., 2019). To more clearly examine how much children persist in trying distinct exploratory strategies, future work might consider the effect of providing solutions when the toy also has non-obvious features that might be suggestive of hidden functions (e.g., Bonawitz et al., 2011).

While children's behavior in the current experiment may reflect their sensitivity to the amount of information to be gained from their own effort, there may be at least one alternative mechanism at play. That is, although the experimenter provided no *explicit* information about task difficulty, telling children in advance that they would later receive answers may have implicitly signaled that that they would likely need help. If so, this pedagogical inference may have undermined children's belief in their own abilities, leading to decreased motivation and persistence. Of course, these two possibilities may also interact: The availability of answers may drive persistence (such that children persist more in situations in which there is more information to be gained) *and* may also signal task difficulty. Ongoing work presents answers to children without any social or pedagogical cues to ensure that persistence is indeed motivated exclusively by the potential for information gain.

While investing less effort in a task when one can gain information another way may reflect a rational process, there may also be adverse effects of providing easily accessible solutions. An open question centers on how the availability of solutions may foster or undermine children's persistence and motivation over time. If adults *often* make solutions available to children (even after children are given the opportunity to attempt a task on their own), children may begin to view effortful learning strategies as inefficient or too costly in general, with possible negative consequences for broader outcomes. For example, those who are more likely to seek out and enjoy cognitive effort tend to perform better academically and demonstrate greater intrinsic motivation (Cacioppo, Petty, Feinstein, & Jarvis, 1996). Thus, the generalizations children make based on the availability of solutions may have longer-term consequences for learning and motivation.

Relatedly, beyond whether or not children view effort as an optimal strategy in a general sense, the availability of solutions may also have an influence on children's curiosity.

Curiosity is often thought to be the result of recognizing a gap in the information one has (Loewenstein, 1994). As children are motivated to seek out information that can fill gaps in their knowledge (e.g., Schulz & Bonawitz, 2007), easily accessible solutions may decrease children's motivation. Indeed, some researchers have speculated that a similar process occurs as a result of easy access to the internet, with curiosity potentially being reduced when learners can access the answers to any question online with little to no effort (Danovitch, 2019). Access to the internet has also been shown to artificially inflate estimates of one's own knowledge (Fisher, Goddu, & Keil, 2015), potentially reducing curiosity because the individual believes that they know more about a topic than they actually do. Providing solutions to children may therefore have similar consequences. Curiosity may also be influenced by the quantity and type of answers provided. That is, providing no answers might decrease curiosity by preventing learners from gaining even partial knowledge about a new topic. Exploring how providing answers influences curiosity is thus an important question for future work.

Here we present preliminary evidence that children's decisions about when to persist are influenced by the information available to them in a novel exploratory learning task. Although children's behavior may demonstrate a rational inference about when additional effort is beneficial, there may be important consequences of providing easily accessible information on future motivation or curiosity.

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