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Children show improved learning of information sampled in their preferred manner *

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***Abstract*— Research showcases children's active role in steering their learning progress by choosing what, when and whom to learn from. Here, we examined differences in children's preferred way to sample their environment and the extent to which children's sampling preferences predict learning outcomes. During training, 3- and 6-year-olds chose whether they wanted to actively sample objects (whose labels they would be presented with) or passively view a set of object-label associations. Following this choice, they were then presented with novel object-label associations in the chosen manner. We found that when given the choice to learn in their preferred manner, children who had a reduced preference for active sampling learned better in the passive condition. This effect was more pronounced in younger children. Our findings highlight the dynamics of children's active learning, with children's learning outcomes being influenced by how they choose to sample their environment. Children are not just active in terms of choosing what to learn but also accurately estimate how they ought to sample their environment.**

***Keywords*— active learning, word learning, sampling strategies, learning preference**

I. INTRODUCTION

Even the young infant shows remarkable selectivity in how they elicit information from the environment. Studies suggest that, from early on, infants and children appear sensitive to other's competence or knowledge states and selectivity elicit information from more knowledgeable than less knowledgeable informants [1, 2]. They also selectively elicit additional social cues from an adult in situations of referential ambiguity [3, 4] and direct their attention to stimuli of optimal complexity [5]. Thus, from early on, the young child appears to strategically explore its environment seeking optimal information sources that will advance knowledge.

Such learning from optimal events has been shown to boost performance, with infants showing improved imitation of actions or learning of words they elicit – through interrogative pointing [6-8]. Later in development, however, the benefits of active learning appear more variable. For instance, while some studies suggest that children learn words better when they choose the order in which they are presented with labels for specific objects [9], others report that children show improved learning when they are presented with object-label associations passively, i.e., with no choice in the specific associations they are presented with [10]. In the pre-school to early school years, strategic information-seeking, driven either by uncertainty or ambiguity, does not appear to be associated with boosts in performance [11, 12]. Thus, in two studies examining early pre-schoolers, children who showed more subjective uncertainty- [11] and ambiguity-driven sampling behaviour [12] did not show improved learning relative to children who did not show such strategic sampling. Similarly, comparing passive learning (when children are explicitly taught) to active learning (when children may or may not choose to attend to speech not explicitly addressed to them), [13] revealed that active learning only reaches levels of performance similar to passive learning around 4.5 to 6 years of age. This pattern is similar to other studies suggesting that active learning in early development (i.e., 3 to 6 years old) resembles adult performance only later in schooling, around 8 years of age [14].

One reason for reported deficits in active learning in early childhood may be that the information provided to the child may not be the information that the child was seeking (c.f., [7, 8]). Here, infants' persistence in pointing when provided with certain kinds of information was interpreted as their sensitivity to the distinction between sought-after and non-sought-after information. However, children may not only vary in the kind of information they are interested in [15, 16] but also in terms of how they want to sample information.

Against this background, the present study investigated whether the extent to which children benefit from active or passive sampling is associated with the extent to which they choose to be an active or a passive learner. Specifically, some children may prefer to receive information passively, and if forced to actively make decisions in learning materials, may perform worse than their counterparts. For instance, one study examined dyads' sampling and learning of novel word-object associations in social contexts (where both parties could see the objects and labels the other partner elicited, [17]). Children showed an initial active learning benefit – learning novel word-object associations better when they actively elicited the labels for objects relative to when they passively observed their social partner elicit the labels for specific objects. Later in the task, however, children maintained this active learning benefit only in interactions with their fathers but not with their mothers or peers.

One interpretation of such findings recruits suggestions that early life experiences – which extends to interactions

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with different social partners – may influence where children align themselves on the explore-exploit trade-off [18]. In particular, children may favour exploration in some social interactions. However, contingent on their experience with certain social partners, children may rely more on exploitation in interactions with these partners (i.e., to rely on information provided by their social partners), given that such interactions have highlighted relevant resources in the past. The transience of active learning benefits may further vary across individual children with some children being more comfortable exploring an environment in some situations while others may be more comfortable relying on the environment to provide them with required resources (i.e., to learn passively).

Along the same lines, previous results suggested that shy children display an aversion to unfamiliarity, which may impact their attention to labelling information in word learning tasks as well as the extent to which such children then learn the presented novel word-object associations [19, 20]. Given shy children's aversion to unfamiliarity, it is also likely that they are less comfortable in exploring the environment and would prefer to receive information passively. Thus, in addition to children showing different benefits from active or passive sampling in different social contexts, there may also be differences in children's preference for specific sampling strategies, with some children preferring to not participate as actively as others.

Given various reasons behind the possibility of children preferring to receive information passively rather than actively, the current study therefore examines the extent to which children's preference to actively steer the information presented to them influences the extent to which they learn from such active information seeking. In an initial warm up phase, children were first trained that they could either have a computer choose an object to be labelled for them (i.e., passive sampling) or choose an object to hear its label (i.e., active sampling). All children then went through a free-choice training block and a no-choice training block. In free-choice blocks, children could choose in each trial whether they wanted the computer to select an object to be labelled or select the object themselves, and then heard the label for the chosen object. The number of trials in this block in which children chose to actively sample objects served as our index of children's preference for active sampling. In no-choice blocks, children were randomly assigned to either an active or a passive sampling condition. Finally, children were tested on their learning of the novel word-object associations as a function of their preference for active or passive sampling and whether the object-label associations were presented in actively or passively sampled trials. Evidence for an overall active learning boost would be improved learning and retention of novel word-object associations when children chose the objects to be labelled as opposed to when they were passively presented with the labels for specific objects. However, if learning success is modulated by children's preference for active or passive sampling, children ought to show improved learning and retention of novel word-object associations that they learned using their preferred sampling strategy.

II. Methods

A. Participants

We tested a total of 165 children. Sixty-one children were excluded from our analysis due to fussiness (n = 5), hearing problems (n = 1), not understanding German (n = 3), technical issues with the tablet (n = 6), and being outside of the pre-registered age range (n = 46). These 46 children were tested despite being outside of our age range (between 8 to 11 years of age) because they were recruited through the local museum, and we were unable to determine their age before testing (see *Section II.D.* for details). Of the remaining 104 children, 51 were 6 years old (24 boys, 27 girls, M_{age} = 76.65 months, age range = 67 – 87 months) and 53 were 3 years old (27 boys, 26 girls, M_{age} = 31.45 months, age range = 27 – 36 months). All children were German speakers with no known cognitive or language impairments. The study was approved by the ethics committee at the University of Göttingen. We obtained written parental consent before each testing.

B. Stimuli

The visual stimuli used in the present study were 24 novel objects taken from the NOUN database [21] while the auditory stimuli used were six novel labels that conform to the German phonotactic rules and have no known familiar neighbour: *anak, bumi, goyang, lauhu, tido*, and *krete*. These novel labels were recorded by a female native German speaker in an enthusiastic, child-directed manner.

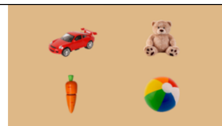
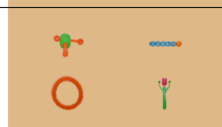
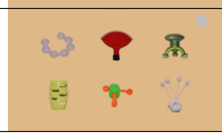
C. Design

The study consisted of a warm-up phase followed by a training phase and a test phase (Table 1). This ordering of phases allowed children to understand the requirements of the task (warm-up phase), be introduced to six novel word-object associations (training phase), and finally be tested on their learning and retention of the trained novel word-object associations (test phase).

In the warm-up phase, children were presented with three sets of four different familiar objects across three trials (see first row of Table 1). In the first trial, children were asked to tap on one of the four objects to hear the label of the object. In the second trial, children were told that it is the computer's turn to choose an object and were shown a pre-determined object being "selected" and labelled. In the third and final trial, children were asked to decide whether they would like to select the next object to be labelled or whether they would like the computer to choose an object to be labelled. Here, they were introduced to a screen with a finger and a computer and asked to tap the finger if they would like to choose the object whose label they would be presented with or the computer if they would like the computer to choose the object whose label they would be presented with. This final warm-up trial aimed to help children understand the requirements of the task and practice choosing their preferred sampling strategy.

The training phase consisted of two blocks, a no-choice training block and a free-choice training block, the order of which was counter-balanced across participants. In the free-choice block, children were allowed to choose for each trial whether they would prefer to choose an object to be labelled (i.e., an active trial) or whether they wanted the computer to choose the object to be labelled (i.e., a passive trial). Children indicated their choices by tapping either on a picture of a finger or a computer as in the warm up trial. Children's choices in these free-choice training trials were used as an index of their preference for active sampling. The possible values of active preference scores were 0 (i.e., 0 active trials, 3 passive trials), 1, 2, and 3.

TABLE I. DESIGN OF THE STUDY

Phase	Number of blocks	Number of trials per block	Example of a trial
Warm-up	1	3	
Training	2 (free-choice and no-choice)	3	
Test	2	6	

In the no-choice block, children were randomly assigned to either an active or a passive sampling condition. In every training trial, children saw four novel objects (see second row of Table 1), one of which would appear again in the middle of the screen and be labelled with a novel word four times. Children never saw the same object twice across trials in the training phase, thus, each trial presented the child with four new novel objects. In active trials, the labelled object was chosen by the child while in passive trials, the object was randomly selected. There were a total of three trials each in the free-choice and no-choice blocks, such that children learned six new label-object association at the end of the training phase.

Next, children progressed to the test phase, with two blocks of six trials each. All six novel objects that were labelled in the training phase (i.e., trained novel objects) appeared on the screen in the test trials (see last row of Table 1) and children were asked "where is the X" in every trial. The location of these trained novel objects was pseudo-randomised so that the target of every test trial never appeared in the same location within each test block. Children received a score of 1 for every correct response made.

D. Procedure

The experiment was carried out using a touch-screen tablet in two settings: the laboratory and a quiet corner of a museum. For the lab setting, parents were first briefed about the study and provided written consent before the task began. For the museum setting, we targeted schools that would be visiting the museum as a class activity. We first provided school teachers with the study's information and consent forms for the children's parents to fill in. On the day in which the class visited the museum, the experimenters met with the teacher to bring a child to a quiet corner of the museum to start with the experiment. As the present study used an interactive tablet task, there was minimal interaction between the experimenter and the child. At the end of the experiment, all children (in both lab and museum settings) were given a book as a token of appreciation. All materials and analysis codes of the present study can be found in https://osf.io/tdwr6/.

E. Analysis plan/Pre-registration

The current study used a 2x2x4 mixed design: choice (free-choice or no-choice), sampling strategy (active or passive sampling) and sampling preference (a score between 0 and 3, a larger score indicates a preference for active sampling).

As pre-registered (https://osf.io/vps7k), we fitted a binomial model with a four-way interaction between block type (free-choice, no-choice), sampling method (active, passive), sampling preference (a score between 0 and 3) and age (in days). Age was z-transformed to ease model convergence. The response variable was a matrix of correct and incorrect responses for each of these conditions. ID was included as a random intercept and sampling method was manually dummy-coded and centred before being included as a random slope within ID. The full model was specified in R as:

*response~block.type*sampling.method*sampling.pref* z.age.day + (1+sampling.method|ID)*

The null model was the same as the full model except that it lacked the four-way interaction and the interaction between *learning method* and *preference score* in the fixed effects part:

*response~block.type*z.age.day*(sampling.method+ sampling.pref) + (1+sampling.method|ID)*

III. RESULTS

The full-null model comparison was significant ($\chi^2(4)=10.45$, $p=0.034$). Two reduced models revealed two significant three-way interactions, one between block type (free choice, no-choice), sampling method (active, passive), and sampling preference ($p=0.011$; Fig. 1) and one between sampling method, sampling preference and age (3-, 6-year-olds, $p=0.032$; Fig. 2).

Although the interactions speak for themselves, exploratory models confirmed, as illustrated in the two bottom plots of Fig. 1, in the free-choice block, the proportion of correct responses was higher in passive sampling trials than in active sampling trials when children had lower preference scores (i.e., had a low preference for active sampling) (significant interaction between sampling method and sampling preference in free-choice block: $\beta=0.73$, SE=0.29, z-value=2.57, $p=0.010$). Furthermore, when comparing the two plots on the left of Fig. 1, the proportion of correct responses in passive sampling trials was lower in the no-choice block than the free-choice block when children had a low preference score (had a low preference for active sampling) (significant interaction between block type and sampling preference in passive sampling trials: $\beta=-0.89$, SE=0.31, z-value=-2.84, $p=0.005$).

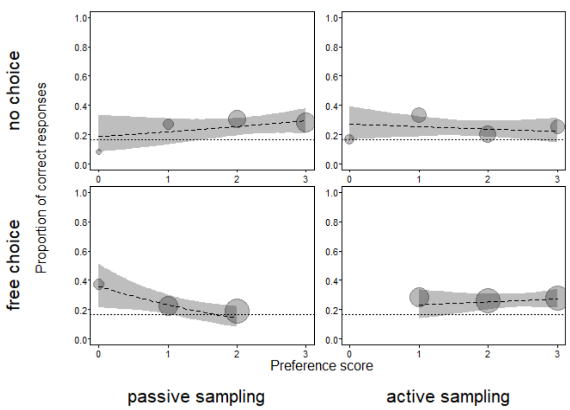


Figure 1. Proportion of correct responses in active and passive sampling trials across the range of sampling preference scores in free-choice and no-choice blocks. The dashed line with grey polygons depicts the fitted model and its 95% confidence interval for age at its average, and the horizontal dotted line indicates chance at 0.16. The area of the circles depicts the number of children with a particular sampling preference score (range: 2 – 37).

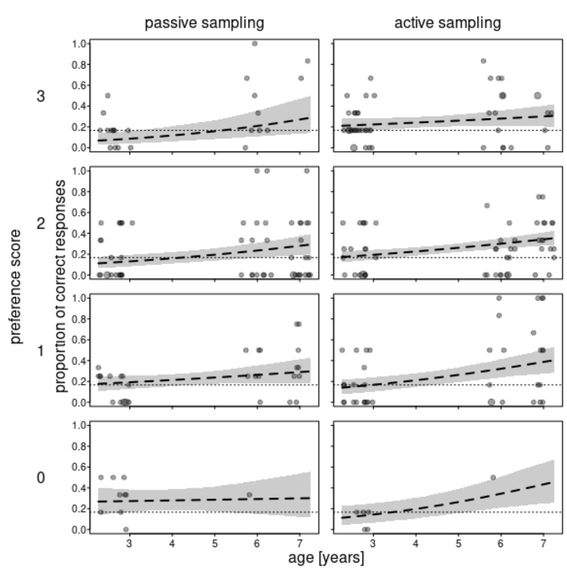


Figure 2. Proportion of correct responses in passive (left panel) and active (right panel) sampling trials across the range of ages and the range of preference scores. The dashed line and grey polygons depict the fitted model and its 95% confidence interval, respectively, and the horizontal dotted line indicates chance at 0.16. The grey circles depict each datapoint.

Finally, Fig. 2 illustrates a developmental trend in children's behaviour. As indexed by the significant interaction between age, sampling method, and sampling preference reported above, older children performed above chance in the test trials in all conditions (right side of all plots), although their performance was better in the active condition (right side of all plots in the right panel) than the passive condition (right side of all plots in the left panel). Younger children (left side of all plots) learned word-object associations above chance in the passive sampling condition (left panel) when their active sampling preference was 0 (last row) but performed *below* chance in the test trials when their active sampling preference score was 3 or 2 (first and second rows, respectively). In the active sampling condition (right panel), these younger children were above chance in the test trials if their active sampling preference was 3 (first row) but were below chance if their active sampling preference was 0 (last row).

IV. Discussion

In the present study, we examined whether children's preference to actively select the kind of information presented to them influences the extent to which they learn from such active information seeking. We hypothesised that were active sampling to be associated with a learning boost, there ought to be overall elevated learning from active sampling trials relative to passive sampling trials. However, if children's preference to actively or passively sample information influences the extent to which they learn actively elicited information, then children ought to show improved learning from trials where information is sampled according to their preferred sampling method. We obtained multiple sources of support for the latter hypothesis. First, when given the choice to sample information in their preferred manner, children who had a low preference for active sampling learned better from passive sampling trials (Fig. 1). Second, children who had a low preference for active sampling showed improved learning in passive sampling trials in the free-choice block relative to the no-choice block (Fig. 1). Third, there was a developmental trend to the pattern of results reported above, with 6-year-olds always above chance (at 0.16) while 3-year-olds showing a trend towards improved learning from passive sampling trials when they had a low preference for active sampling (Fig. 2).

Taken together, these findings suggest that children did not merely show improved learning of information they actively elicited. Rather, children showed improved learning of information that they sampled in their preferred manner. In other words, children did not only choose what to sample in steering their learning progress but also how they wanted to sample information. We discuss these findings in further detail below.

A. *Sampling preference is associated with learning outcomes*

A key finding of the current study is that – in blocks in which children could choose how to sample information – children with a lower preference for active sampling showed improved learning of object-label associations presented in passive trials than active trials. In contrast, children with a higher preference for active sampling showed improved learning of object-label associations presented in active trials than passive trials. Our findings extend previous research on children's active learning to demonstrate that an active boost is observed only if children are intrinsically motivated to actively select their learning materials. Conversely, we also found that passive learning did not necessarily lead to worse learning. Rather, children who prefer to learn passively – by displaying a lower preference for active sampling – actually showed poorer performance at test if they were forced to learn actively in the training phase.

We suggest that this pattern of results may help explain – in part – the diversity of findings regarding an active learning boost in early childhood. Our findings highlight the transience of active learning, especially in early development and suggest caution in applying active learning across the board. There is no one-size-fits-all sampling strategy that is unanimously associated with learning boosts. A better approach to allowing children greater control over their learning progress may be to allow them to choose *how* they want to sample information and learn, with our findings suggesting that children show improved learning of information sampled in their preferred manner. However, as we discuss in further detail below, this may be contingent on the sense of control that children feel during task completion.

B. A sense of control boosts learning

Given that children were randomly assigned to active and passive sampling conditions in the no-choice blocks, we expected that children show improved learning when they happened to be assigned to the group sampling information in their preferred manner. However, we found no evidence that children's preference for active or passive sampling influenced learning from active or passively sampled object-label associations in the no-choice blocks.

To a certain extent, this was contrary to our expectations inasmuch as we did not predict a difference in the influence of sampling preferences on performance in free-choice and no-choice blocks. However, our pre-registered model yielded a significant interaction between *block type* (free-choice, no-choice), *sampling method* (active, passive), and *sampling preference*. In particular, in passive sampling trials, the proportion of correct responses was lower in the free-choice relative to the no-choice block when children had a higher preference for active sampling.

We suggest that this may be due to the flexibility of learning offered in the free-choice blocks relative to the no-choice blocks. Thus, children may have felt more control in steering their learning in the free-choice blocks, revealing differences in learning outcomes based on their sampling preferences in such blocks, as opposed to the no-choice blocks. Such an interpretation is in keeping with suggestions made in [9], that a sense of control enhances learning in children. In particular, in [9], children in an active condition – where children were allowed to choose the order in which the objects were labelled – retained novel word-object associations better than children in a passive condition – where the order in which the objects were labelled was pre-determined. The researchers explained this finding by suggesting that being allowed to tap on an object (and thus, "choose" the object) as opposed to only tapping on a button (akin to allowing the device to choose) gave children a sense of control, which improved their learning performance.

Our findings are also in keeping with previous studies such as [22], which showed that in some cases, children's learning of what appears to be actively sampled information may be impaired due to their tapping being more impulsive (in the sense of engaging with an object regardless of the need to elicit information about this object) than active (in the sense of actively seeking information about that object). Bringing together [9] and [22], we suggest that given children's reduced sense of control in the no-choice blocks, children in this block may be displaying more impulsive tapping in active trials, thereby impairing learning across the board.

Importantly, we note that the present study highlights the extent to which children's sense of control may improve learning even in passive trials. Specifically, even when children prefer to sample passively (i.e., they have a lower preference for active sampling), giving them a chance to indicate that preference enhances learning. Our findings, therefore, raise interesting possibilities of how to tailor learning to the preferences and interests of the child, both in terms of how to learn as well as what to learn.

C. Age differences and learning preference

There was a developmental trend in the extent to which children's sampling preferences influenced learning from active and passive trials. In particular, our pre-registered model reported a significant interaction between *sampling method* (active, passive), *sampling preference*, and *age* (3-, 6-year-olds). Overall, we found that children's learning in both active and passive sampling trials improved with age (Fig. 2). This speaks to a critical developmental trend in children's learning – which further explains the diversity of findings regarding an active learning boost in early childhood. In particular, if older children show improved learning from passive trials, then this may explain why the active learning boost may vary across development [13, 14].

That 6-year-olds were always above chance (at 0.16) may speak to the greater efficacy of learning in older children, in general, with children at this age having already started formal schooling and more developed executive function. On the one hand, this finding might be taken to suggest that there may be little benefit in allowing older children active control over their learning progress, especially in simple word learning tasks. Indeed, we note that two other studies similarly reported finding no evidence for an active learning boost in children of a similar age [11, 12]. Obviously, such a broad-reaching conclusion ought to be tempered by the fact that it rests on a null effect, thereby, necessitating further examination of this conclusion in future research. Nevertheless, we highlight the importance of examining such a conclusion given the costs of encoding active control, especially in children's educational settings.

In contrast, with 3-year-olds, we observe that children who displayed a waning preference for active sampling showed improved learning from passive trials. Here, we also highlight the visual difference between active and passive sampling trials for 3-year-old children with a high passive sampling preference: 0 on the preference score (Fig. 2). In particular, children with a high passive sampling preference learned above chance from passive trials but not from active trials. Especially at this young age, children who had an overwhelming preference to learn passively, learned more object-label associations presented in passive trials. However, when these children were forced to choose the object whose label they would be presented with possibly faced a cognitive overload, thereby impairing learning. Taken together, our findings highlight a sensitive period at 3-years of age in which learning may be particularly susceptible to differences in children's preference for specific sampling strategies, which may be relevant to learning outcomes in even simple word-learning tasks.

We only interpret the learning preference measured in the present study with regard to children's preference at the moment and by no means as an indication of children's long-term sampling preferences. In particular, we do not know whether or how this sampling preference and the associated learning outcomes vary between different tasks and learning contexts and social partners. Indeed, in the present study, we only asked children to choose the novel object whose label they would be presented with. Our findings may not be generalisable to other tasks, such as when the novel objects can be grouped into real-world object categories, or when children are asked to learn the functions (instead of the labels) of these novel objects (c.f. [8]). Furthermore, an important next step would be to examine whether passive learning similarly enhances children's learning of previously uncertain or ambiguous events. For instance, recent work [11] suggested that 5-year-olds do not display subjective uncertainty-driven sampling: despite indicating that they are unfamiliar with the label of a particular object, they do not strategically sample this object when given the chance. Could children's sampling preference explain such findings, with children who have a higher active sampling preference showing increased uncertainty-driven sampling in such tasks? Future studies could also explore the possibility of culture coming into play with children from cultures that emphasise greater reliance on learning from adults showing different preferences relative to other more child-centric cultures.

The present study therefore opens up a host of interesting questions for our understanding of active learning in early development. Critically, we showed that children are not merely active in choosing what to learn but also in terms of how to learn, showing improved learning of information sampled in their preferred manner. Active learning, we suggest, does not befit a one-size-fits-all approach and requires further examination of the extent to which active learning benefits may vary across development, across different social contexts, and across children's individual preference for active learning.

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