EÖTVÖS LORÁND UNIVERSITY
FACULTY OF EDUCATION AND PSYCHOLOGY

Liszkai-Peres Krisztina

Development of memory: Update and revision

Doctoral Thesis

Supervisor: Dr. Király Ildikó

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INTRODUCTION

Developmental studies applying long-term imitation method usually investigate basic mnemonic features like retention interval or the role of mnemonic cues (pl. Bauer, Hertsgaard, & Dow, 1994; Bauer & Leventon, 2013). Yet, only a handful of studies investigated, whether imitation differs after a shorter or a longer delay. One of them is the study of Simpson and Riggs (2011), where 3-4-old children imitated an action precisely after a shorter delay (few minutes), but on the long term (a week) only the relevant actions for goal attainment were recalled during imitation. In another study, older children (9-16 years) and adults demonstrated similar imitative behavior (Kline, Gervais, Moya, & Boyd, 2020). Based on these findings events are recalled as goal oriented action sequences on the long term. Yet, it is unclear whether irrelevant steps are forgotten or could be retrieved, if it is required. The study of Williamson, Meltzoff, and Markman (2008) is related to this question. In their experiment, 3-year-old children's task was to open a magic box, which they have met previously. A group of children had easy previous experience with the box, while the other group had difficulties. After playing with the box, the experimenter showed a new opening method. Children with easy prior experience did not imitate this new method, but children with difficult experience applied it. From the perspective of memory the important finding was that, if the opening became difficult in a later session, children with easy prior experience could retrieve the model's method even though they did not imitate it previously (Williamson et al., 2008). In a similar vein, in a theory of mind study by Király, Oláh, Csibra, and Kovács, (2018) 3-year-old children were able revise retrospectively an event after acquiring an important information, that changed their beliefs about the other person's knowledge. Thus both studies strengthened the assumption that previously irrelevant actions could be recalled if necessary.

Retaining specific events is a characteristics of episodic memory. Moreover, in the previously mention studies the task was not only to recall an irrelevant information but to reconsider its relevance. According to the evolutionary theory of Klein, Cosmides, Gangi, Jackson, and Tooby, (2009) the function of episodic memory might lie exactly in this review process, as only episodic memory offers the possibility to reconsider our assumptions and beliefs about previous events in light of a new information that does not

fit in our previous interpretation. Returning to our previous question, in a shorter interval children are able to recall and reconsider irrelevant actions, but are they able to do it after a longer delay, as well?

Reconsideration of memories could be induced by two events. One of them is, when a former relevant action became less relevant or irrelevant. For example, we have driven so far only cars with manual transmission, but now we are in a car with automatic transmission. Some part of our knowledge about transmission became irrelevant, thus we need to **update** our behavior to the demands of the new circumstances.

The other way is, when we need to revise the meaning of a former event in light of new information. For example, we have lost our purse, and as we try to remember about past details suddenly we understand the meaning of an unpleasant experience from the tram, where someone got really close to us (most possibly to steal our purse). In this case **revision** of a former irrelevant event was needed.

The aim of studies presented in the thesis was to investigate the mnemonic process of revision and update in two age groups, 2- and 3-4-year-olds. The studies consisted of two sessions with one-week delay between them. On the first session the model showed a goal attainment event, where a tool was used. The tool was either relevant or irrelevant in goal attainment. After the demonstration children could try the same situation, this was the short-term memory test. After a week there was not any demonstration, but the relevance of the tool has changed: it either became relevant or irrelevant (the opposite of its former relevance).

Hypotheses

1) In the short-term test children imitate regarding the tool's relevance (Gergely & Csibra, 2003), thus
   a) the tool will be used, when it is relevant.
   b) tool use will be omitted, when it is irrelevant.
2) In the long-term test children are able to reconsider their previous experiences, thus
   a) the former irrelevant tool will be revised as relevant, and it will be used for goal attainment (revision).
   b) the former relevant tool will be reconsidered as irrelevant, and tool use will be omitted (update).

UPDATE AND REVISION

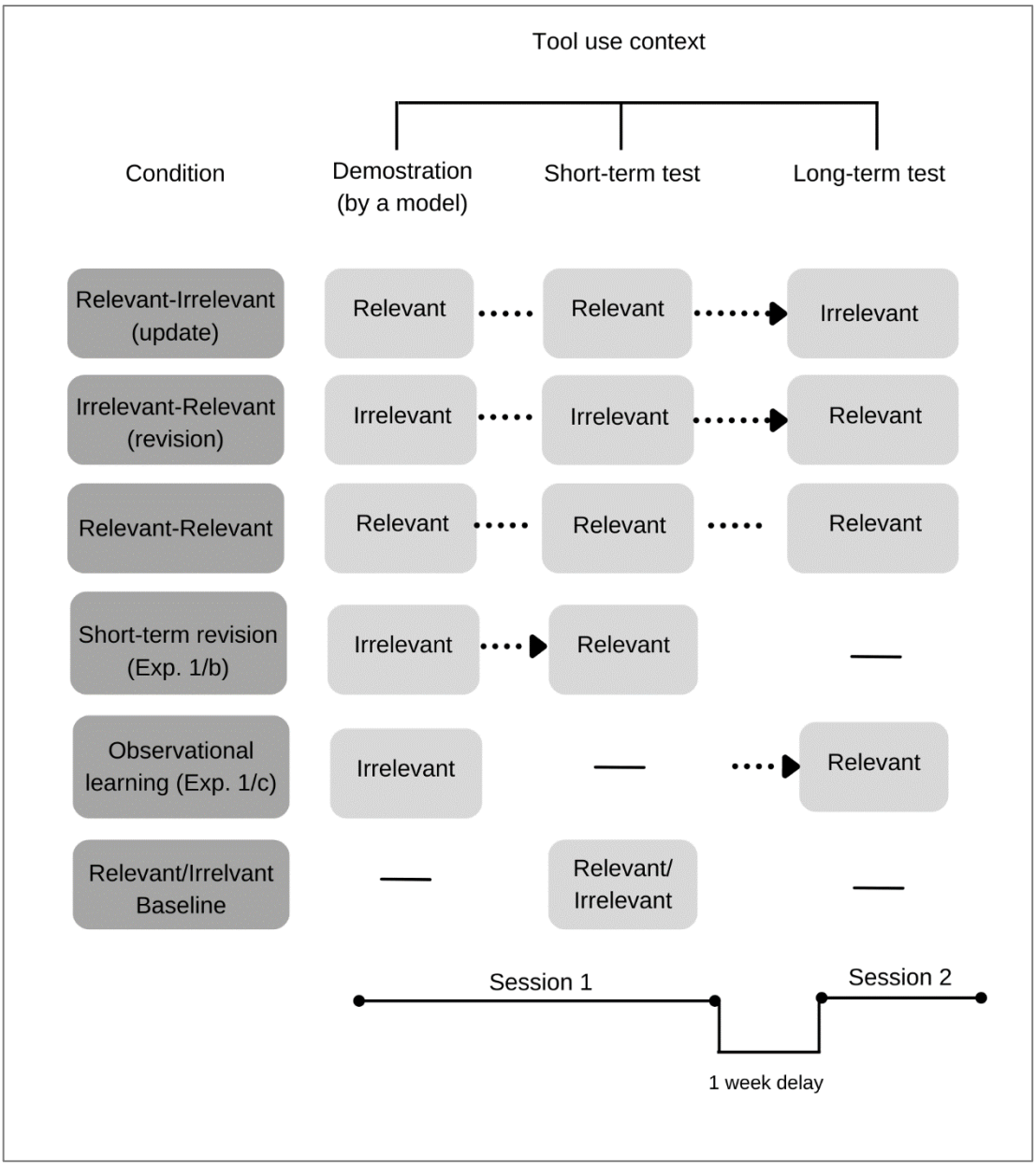
AT THE AGE OF TWO

1. Experiment 1/a

1.1. Method

Participants were N = 78 infants. Their ages ranged from 19 to 27 months, with a mean of 24 months (SD = 1.59 month). Children were randomly assigned to the following conditions: 18 children (7 males) were in the Irrelevant-Relevant condition, 18 infants (9 males) in the Relevant-Irrelevant condition, 18 infants in the Relevant-Relevant condition (12 males), 12 infants (7 males) in the Relevant Baseline and 12 (8 males) in the Irrelevant Baseline condition.

All experimental conditions (except from the two baseline conditions) contained two sessions (short-term and long-term test). The delay between the sessions was one week. The first session began with the demonstration of toys and a tool which could be used for reaching the toys. The difference between conditions was whether the tool was needed for attaining the tool or not. In other words, was its use relevant (the only way to reach the toy) or irrelevant (the toy could be reached with hands). In the Relevant-Irrelevant condition, tool use was relevant in the short-term test and became irrelevant in the long-term test. In the Irrelevant-Relevant condition the design was reversed: tool use was irrelevant in the short-term test and became relevant in the long-term test. A control condition was also applied to measure forgetting rate. Here, in both test session tool use was relevant. Baseline conditions contained only one test session, where spontaneous tool use was investigated in a relevant and in an irrelevant situation. Baseline conditions were executed without demonstration (1. Figure). A test session contained three trials, where children received a score of 0 or 1 for each trial, resulting in an overall score ranging from 0 to 3.



1. Figure Design of the study with 2-year olds. The figure shows the conditions regarding the relevance of tool use. The arrow signs the change of context. On the bottom of the figure the temporal design of the study is shown.

1.2. Results

1.2.1. Short-term memory test

Kruskal-Wallis test revealed strong evidence of difference between groups, $H(4) = 70.20$, $p < .001$, $\eta^2 = .91$. Dunn's pairwise tests with Bonferroni correction revealed that, when the tool was first relevant in goal achievement (Relevant-Irrelevant), children used it significantly more than in the baseline conditions (compared to Relevant Baseline: $p <$

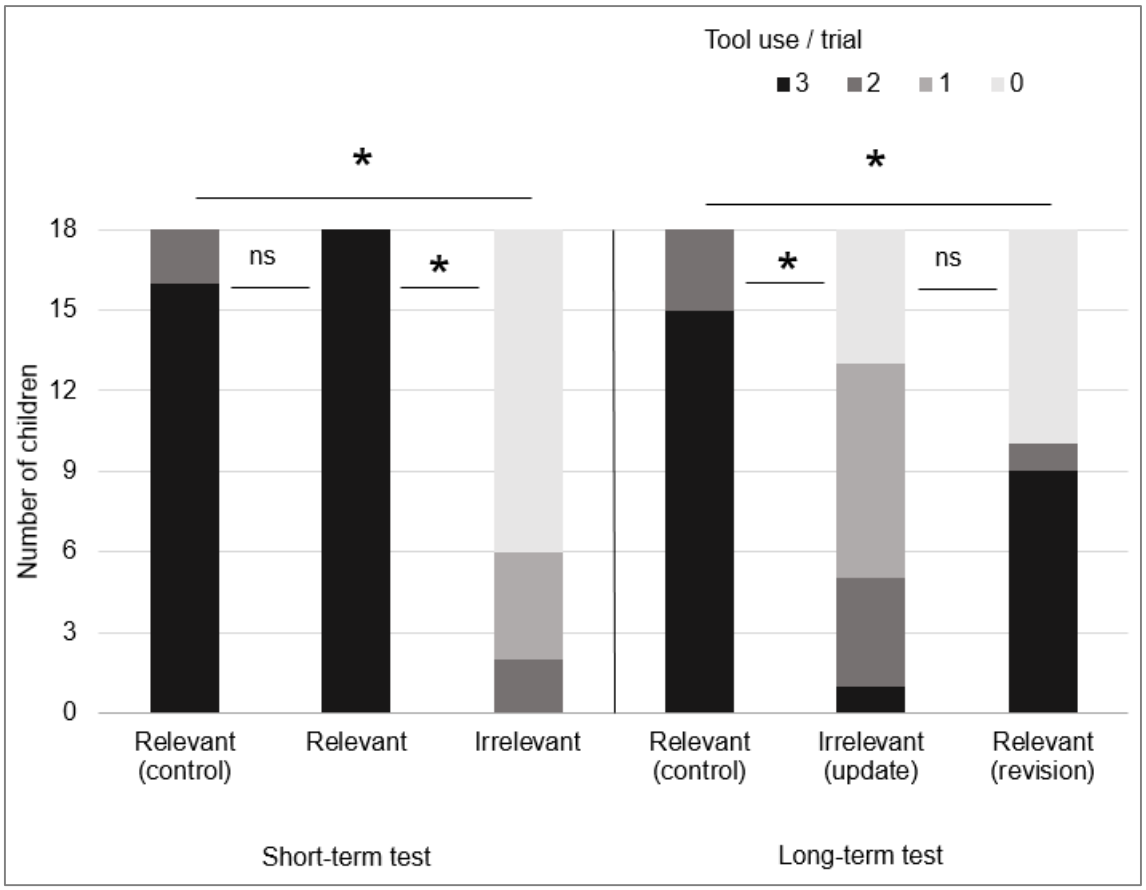
.001; Irrelevant Baseline: p < .001). Similarly, children used the tool more in the relevant context of Relevant-Relevant condition than in the baseline conditions (compared to Relevant Baseline: p < .001; Irrelevant Baseline: p < .001). However, when the tool was irrelevant first (Irrelevant-Relevant), children used the tool at a rate similar to the baseline conditions (compared to Relevant Baseline: p = 1; Irrelevant Baseline: p = 1) (**Hiba! A hivatkozási forrás nem található.**).

Results showed that children imitated tool use regarding its relevance.

1.2.2. Long-term memory test

Kruskal-Wallis test also revealed strong evidence of difference between groups, H(4) = 45.49, p < .001, η^2 = .57. Dunn's pairwise tests with Bonferroni correction showed that, when the tool became relevant at the second time (Irrelevant-Relevant), children used it more than in the baseline conditions (compared to Relevant Baseline, p = .027; Irrelevant Baseline: p = .012). Similarly, when the tool remained relevant (Relevant-Relevant) children used the tool more than in the baseline conditions (compared to Relevant Baseline: p < .001; Irrelevant Baseline: p < .001). However, when the tool lost its relevance (Relevant-Irrelevant) children used the tool at a rate similar as in the baseline conditions (compared to Relevant Baseline: p = .247; Irrelevant Baseline: p = .130) (2. Figure).

The findings of the long-term test showed that the difference in imitation between the two tool use contexts diminished. As the control condition for forgetting showed children are able to remember well previous events, but when revision is also needed, it becomes more difficult for children. In contrast, update of an event seems less effortful.



2. Figure Comparisons between conditions in the short-term and long-term tests.

2. Experiment 1/b: Short-term revision

The difficulties in revision could be due to elapsed the time between sessions. After a week, specific event elements might be missing making revision nearly impossible. We supposed that if relevance of tool use changes already in the short-term test, after demonstration, revision of tool use will be less difficult than after a week.

Hypothesis

Children will use the tool more in the Short-term revision condition compared to the original (long-term) Revision condition.

2.1. Method

In the Short-term revision condition 18 children were involved. The original Revision condition was modified so that after the irrelevant tool use demonstration relevance of

tool used changed to relevant in the short-term test. The test consisted of only one session, the long-term imitation test was missing here.

2.2. Results

The long-term imitation test from the original revision condition was compared to short-term revision condition. Mann-Whitney test did not show any difference U = 124, p = 0.161, $\eta^2 = 0.04$.

3. Experiment 1/c: Observational learning

In the Revision condition information comes from two sources: from the demonstration and the short-term test. The experience from double source could affect memory. First, the own motor action might generate stronger memory trace compared to the demonstration. Second, it might be difficult to differentiate information stemming from demonstration and the short-term practice (similar to source memory problems). To avoid the issues based on the double source, in the Observational learning condition the short-term test was elicited. In this way children could learn about the tool only from the demonstration. In this condition 18 children were involved.

3.1. Results

The long-term test of the original Revision condition was compared to the Observational learning condition. Mann-Whitney test did not show any difference between the two conditions U = 157, p = .857, $\eta^2 = 0.001$.

UPDATE AND REVISION

AT THE AGE OF 3-4

In this study we would like to access an age group where update and especially revision causes less difficulty. Based on previous studies 3-4-year-olds are able to adapt to changes stemming from the context (Király et al., 2018; Scarf, Gross, Colombo, & Hayne, 2013; Suddendorf, Nielsen, & Von Gehlen, 2011; Williamson et al., 2008). However, this age group is prone to overimitation, when all action steps are copied irrespective of their relevance (Hoehl et al., 2019). This phenomenon is explained by the increased importance of social motivations (Nielsen, 2006; Over & Carpenter, 2012). Yet, long-term imitation studies showed that overimitation is less striking after a longer delay (Kline et al., 2020; Simpson & Riggs, 2011) and in some cases children consider also the relevance of an action during imitation (Williamson et al., 2008).

Hipotheses

1. In the short-term test children imitate regarding the relevance of tool use, thus
    a. the tool is used, when it is relevant.
    b. tool use is omitted, when it is irrelevant.
2. In the long-term test
    a. the tool will be used more in the changed relevant test compared to the previous irrelevant test (revision).
    b. the tool will be less omitted in the changed irrelevant context compared to the previous relevant test (update).

1. Method

In the study 66 children were involved (33-54 month-olds, mean = 43.5 ± 4,1). Participants were randomly assigned to the Irrelevant-Relevant (n=18), Relevant-Irrelevant (n=18), Short-term revision (n=18) and Relevant Baseline (n=12) conditions. The procedure was identical with the study with 2-year-olds (1. Figure).

2. Results

2.1. Short-term memory test

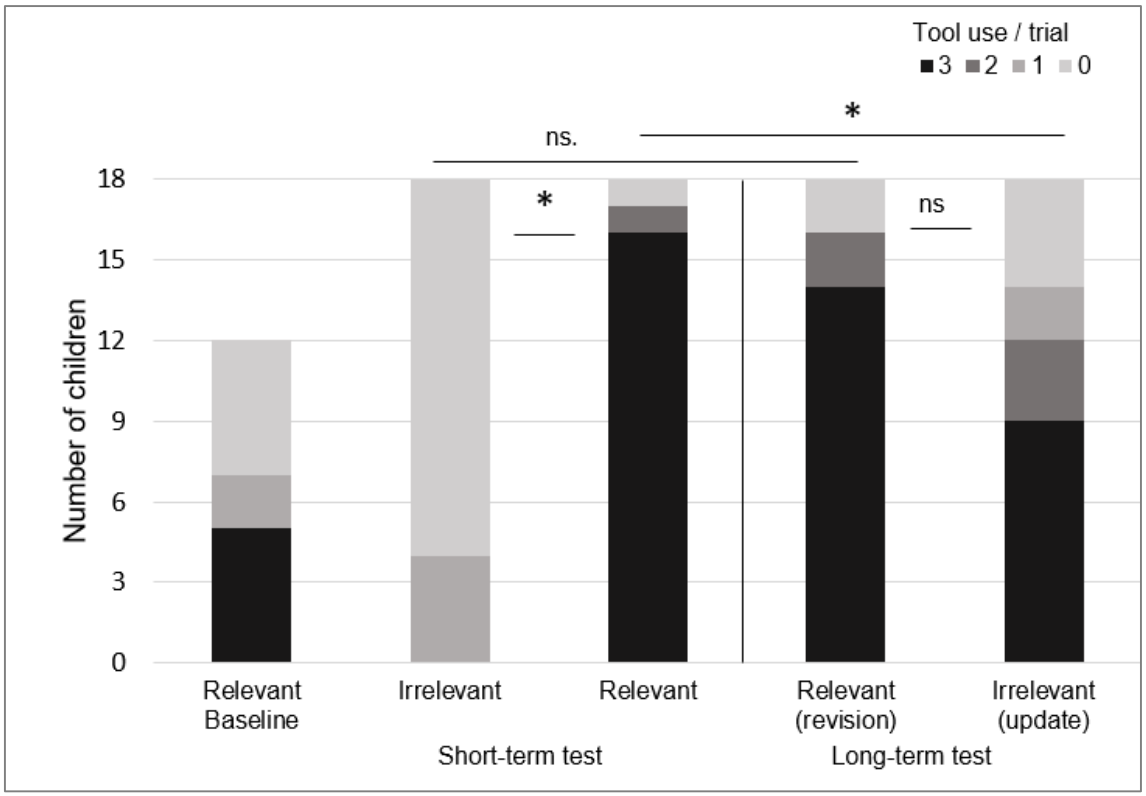
In Session 1, conditions differed significantly in tool use, Kruskal-Wallis H(3) = 43.07, p < .001, η^2 = .65. Dunn's pairwise tests with Bonferroni correction revealed that Relevant Baseline (Mean = 1.17, SD = 1.4) differed from the conditions where tool use was relevant (Relevant-Irrelevant (Mean = 2.78, SD = 0.73), p = .019; Short-term revision (Mean = 2.83, SD = 0.71), p = .011), but not from the condition where the tool use was irrelevant in this first session (Irrelevant-Relevant (Mean = 0.17, SD = 0.38), p = .346) (3. Figure).

2.2. Long-term memory test

Mann-Whitney U test did not show any difference between the Irrelevant-Relevant (revision) and Relevant-Irrelevant (update) condtions, U = 104.5, $p = 0.068$, $\eta^2 = 0.092$ (3. Figure).

2.3. Comparison of relevant contexts, and comparison of irrelevant contexts

Similar imitation on the relevant and irrelevant long-term tests might be the caused by two reasons: previously relevant tool use was less omitted in the irrelevant context, or revision of the former irrelevant act caused difficulties. This question was investigated through comparison of first and second session relevant tests and similarly, comparison of first and second session irrelevant test. Comparison of relevant tests did not show any differences, Mann-Whitney U = 153.5, $p = 0.654$, $\eta^2 = 0.02$. Comparison of irrelevant tests showed significant difference, Mann-Whitney U = 45, $p < 0.001$, $\eta^2 = 0.38$. Children used the tool more if the second session was irrelevant (3. Figure).



3. Figure Comparisons between conditions in the short-term and long-term tests. The figure also shows results of the same contexts comparisons (relevant-relevant, irrelevant-relevant)

2.4. Short-term revision

Finally, Short-term revision condition was compared with the long-term test of Relevant condition. Mann-Whitney test did not show any difference U = 145, $p = 0.324$, $\eta^2 = 0.01$.

COMPARISON OF EXPERIMENTS WITH 2 AND 3-4-YEAR-OLD CHILDREN

As the same paradigm was used in the study with 2 and 3-4-year-old children, we could directly compare the performance of the two age groups.

Hypotheses

1. Irrelevant-Relevant (revision) condition
    a. in the short-term test there will be no difference between the groups, because they similarly omit tool use regarding its irrelevance
    b. in the long-term 3-4-year-olds use the tool more compared to the 2-year-olds, because of their improved mnemonic skills.
2. Relevant-Irrelevant (update)
    a. on the short-term there will be no difference between the groups. As it is simple imitation task and there is no other way to reach the toy, children will use it in both age groups.
    b. on the long-term 3-4-year-olds update their behavior less, and use the tool more compared to 2-year-olds. With age social motives got stronger resulting more fixedness to previous experiences.

1. Method

For the analysis we reused the Relevant-Irrelevant and Irrelevant-Relevant conditions from the experiment with 2 and 3-4-year-olds (2-year-olds: N = 36 (18/condition), mean age: 24,33 months ± 1,23 month; age interval: 22-27 months; 3-4-year-olds: N = 36 (18/condition), mean age: 43,56 months ± 4,61 months; age interval: 33-54 months).

2. Results

In the short-term test of the *Irrelevant-Relevant (revision)* conditions there was not any difference between the two age groups, U = 132, $p = 0.35$, $\eta^2 = 0.025$. On the long-term

test we found marginal significant difference, U = 100.5; $p = 0.051$, $\eta^2 = 0.105$. 3-4-year-olds used the tool more in the revision condition.

In the short-term test of the *Relevant-Irrelevant (update)* conditions there was not any difference between age groups, Mann-Whitney U = 144, $p = 0.58$, $\eta^2 = 0.009$. On the long-term test 3-4-year-olds used the tool more compared to younger children, U = 93.5; $p = 0.029$, $\eta^2 = 0.13$.

Based on the results children in both age groups imitated similarly in the short-term test: used the tool, when it was relevant, and omit its use, when it was irrelevant. In the long-term test of the revision condition older children performed better than younger ones. However, in the update condition younger children omitted the tool more easily compared to older children.

DISCUSSION

In the short-term test our hypothesis was approved, namely that children take into consideration the context in goal attainment. In the long-term test we found that imitation in the relevant and irrelevant contexts did not differ spectacularly. This results means that previous experiences affected performance in the later test. However, this phenomenon was similar in both age groups, the reasons behind it might differ. As comparison of the two age groups showed, 2-year-olds had more difficulty with revision than older children. In contrast, 3-4-year-olds updated their behavior less in the second, irrelevant context. Thus we suppose that indifference of imitation in the study with 2-year-olds stems from the limited revision capacity, but indifference in the study with 3-4-year-olds stems from the fixedness to their previous relevant solution.

1. Revision

Revision could be a good indicator of episodic capacity, because here recall and reevaluation of the previously irrelevant step is necessary. To evoke this mechanism, first a context was set up, where tool use was an irrelevant step. Fortunately, both age groups seem to evaluate tool use as irrelevant, as most of the children did not use it. Thus the design and setup supported instrumental imitation, when the goal is more important, than the means leading to it (Over & Carpenter, 2012). This is also in line with the rationality principle, which claims that goals are reached in the most simple way in the given circumstances (Gergely, Bekkering, & Király, 2002). Also, efficiency of the tool could affect imitation (DiYanni & Kelemen, 2008; Fong, Imuta, Redshaw, & Nielsen, 2021).

On the long-term test, half of the 2-year-olds and most of the 3-4-year-olds was able to revise the previously irrelevant act. How could we explain this result from the perspective of memory? At the age of two, event memory might be responsible for goal oriented imitation, that retains mostly relevant acts. The better performance of 3-4-year-olds could be due to their improved event memory skills. However, we also suppose that episodic memory is also involved, as the task requires not just recall but also reconsideration of the relevance of tool use. This latter mechanism is similar to the "spoon" test (Suddendorf et al., 2011; Tulving, 2001), that is also claimed to tap episodic

capacities. The difference between the two tasks, that the spoon task requires to solve a problem in the future based on a past experience, the revision paradigm only requires to solve a problem in the present based on the past. From this point of view, the revision paradigm could be easier for children, as it lessens the cognitive load on children by eliminating planning for the future. Another advantage of the revision task is that it is "only" about the past, which is closer to the original meaning of episodic memory compared to newer views involving episodic foresight, as well.

2. Update

The short-term test of the update condition was a classical imitation paradigm, where a model showed an unusual action, that was necessary for goal attainment. Children in both age groups understand this, and imitated the model's behavior. However, when the relevance of the tool's efficiency was questioned in the long-term test, only 2-year-olds adapted to the context and omitted tool use, 3-4-year-olds still used the tool in the irrelevant context, as well.

The flexible performance of 2-year-olds could be explained again with the principle of rationality (Gergely & Csibra, 2003), they simply chose the most simple action in the given circumstances. The inflexible behavior of 3-4-year-olds could be explained with the characteristics of the task, as the update required reconsideration less, as the task could be still solve with the tool, only it was a bit inconvenient. Beliefs about the efficiency of the tool could also affect imitation. As the tool was effective previously, children might have learnt that it is useful, and used this heuristic also later. This could be a form of functional fixedness, when we insist on our previous solutions (German & Barrett, 2005). Functional fixedness grows stronger with age (German & Defeyter, 2000), thus it could explain age group differences, as well.

Another line of explanation of the inflexibility of older children lies in the role of strengthening social motives (Over, 2016; Over & Carpenter, 2012). It is possible, that children not only evaluate the tool's function higher, but also the model showing it. Based on the literature, reliable persons are imitated more precisely compared to an unreliable one (eg. Zmyj, Buttelmann, Carpenter, & Daum, 2010). Here, showing an effective tool might increase the reliability of the model. On a group level, normativity is also a possible

explanation, when children learn from the task, that they should achieve the goal via the demonstrated method (Kenward, 2012; Keupp, Behne, & Rakoczy, 2013).

3. Take home message

Methodically, experiments showed the importance and usability of imitation for studying memory. It is worth to compare imitation in the short-term and long-term not just from the point of view of memory, but it can serve valuable information about other cognitive skills like social cognition. Another methodological finding that even older children take into consideration context and relevance of actions during imitation, that could be used as a manipulation for other tasks, as well.

Conceptually, we have learnt from the results that revision is a developing skill at the age of two, but it is more stable at the age of 3 and 4. On the other hand, social motives grow stronger with age, resulting a different imitation patterns at the age of 2 and 3-4.

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