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Animates engender robust memory representations in adults and young children

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ABSTRACT

The animate monitoring hypothesis proposes that humans are predisposed to attend preferentially to animate entities in the environment (New, Cosmides, & Tooby, 2007). However, there have to date been no developmental investigations of animate monitoring in younger populations, despite the relevance of such evidence to this hypothesis. Here we demonstrate that adults and preschoolers recall a novel sequence of action with greater fidelity if it involves an animate over an inanimate. Experiments 1 (adults) and 2 (preschoolers) provide initial support for this phenomena, when a familiar animate (a dog) is used in the sequence instead of a block. Experiment 2 also revealed that a beetle is not clearly superior to a block, hinting at a possible hierarchy of animacy. Experiment 3 provided the clearest evidence for this memory advantage in preschoolers, when a novel animate that was perceptually identical to two other inanimate controls enhanced memory for the sequence. These results indicate that animate monitoring does not require extensive experience to develop, and could possibly be the result of innate dispositions.

1. Animates engender robust memory representations in adults and young children

In modern Western society humans spend the majority of their time surrounded by fellow humans. From household to household there is variability in the amount of exposure westerners have to other animals, depending on the number and type of pets in the home. But in prehistoric times human exposure to other animals was vastly greater. Although the social nature of humanity necessitates a high degree of contact with conspecifics, we evolved embedded in diverse ecosystems, one animal among many. Like all animals we needed to know which animals were threats to be avoided and which could largely be ignored, and like all predatory animals which were sources of food. Most importantly, we needed to keep track of the ones upon which our survival depended.

New, Cosmides, and Tooby (2007) were the first to articulate what they referred to as the animate monitoring hypothesis (AMH): that the human cognitive system evolved to develop heightened attention to animate entities (human or nonhuman) in the environment. Across several experiments they demonstrated that people more rapidly detect changes to animate entities in static scenes than to other living sessile entities (plants) and moving nonliving entities (vehicles). Further support for the AMH comes from evidence that animates are detected more quickly in visual search tasks (Jackson & Calvillo, 2013), are more frequently reported in attentional blink (Guerrero & Calvillo, 2016) and inattentional blindness tasks (Calvillo & Hawkins, 2016; Calvillo & Jackson, 2014), and receive longer fixations (Yang et al., 2012).

The above tests of the AMH rely on differential processing based on in the identification of specific visual features (e.g., faces, legs) that distinguish many (but not all) real-world animates from inanimates. However, Hagen and Laeng (2016, 2017) have recently called such evidence into question. In their first set of studies (Hagen & Laeng, 2016) they found no detection advantage for animates when extraneous visual dimensions (visual complexity, luminance, etc.) were balanced. In their second set of studies (Hagen & Laeng, 2017) they found that post-attentive processing of animate stimuli – for instance, more efficient encoding of shape and/or faster identification – provides sufficient explanation for why animates are more likely to survive the attentional blink. These studies suggest that any advantage adults have at detecting animates more robustly than inanimates may have an experiential explanation.

However, if animacy is the core reason for heightened attention it should be observable even when stimuli are visually identical in form. Motion is a central feature of animacy, and Heider and Simmel (1944) famously demonstrated that people readily ascribe animate status to novel, perceptually abstract entities that lack the visual features of real-

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world animates provided they move in an animate (or intentional) fashion. Interestingly, when abstract targets undergo animate motion they are detected more quickly than when they undergo inanimate motion (Pratt, Radulescu, Guo, & Abrams, 2010). Scholl and Gao (2013) have argued that animacy is a fundamental aspect of visual perception in such cases, from evidence with similarly animate "wolves" (Gao, McCarthy, & Scholl, 2010). They found that such wolves and their targets ("sheep") are attended to with higher fidelity than control motion stimuli (Scholl & Gao, 2013). van Buren and Scholl (2017) demonstrated that increased attention also has downstream effects on memory, as they demonstrated that spatial memory is better for targets that are tracked by "wolves" relative to various inanimate/less animate controls. In such cases increases in attention and memory for animates cannot be reduced to differences in object-based visual features.

A distinct line of evidence for the AMH that obviates all perceptual concerns comes from research on memory for animate stimuli and events (e.g., Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013). In these cases, it is the activation of a deeper concept of animacy, beyond the presence of object or motion features, that is the source of increased attention, storage, and/or recall. Nairne and colleagues have demonstrated that animate words are remembered with greater fidelity than inanimate words (for a review see Nairne, VanArsdall, & Cogdill, 2017; see also Bonin, Gelin, & Bugaiska, 2014 for memory for images). In one particularly compelling experiment VanArsdall, Nairne, Pandeirada, and Blunt (2013) taught participants novel words (e.g., "FRAV") embedded in sentence contexts that implied animate status (e.g., "enjoys cooking") or nonliving status (e.g., "has a hollow center"). Novel words were recalled with greater frequency when embedded in animate sentences as compared to inanimate sentences. Cogdill (2015) also demonstrated that animates can confer a mnemonic advantage to inanimate objects, as objects that are touched by an animate are recalled more robustly than objects touched by inanimates. Both of these findings have nothing to do with lexical or semantic differences between the words themselves; It is instead the case that activation of animacy as a concept improves attention, retention, and/or recall for the details of that event.

All previous work on the AMH has relied on evidence that adults process animates differently than inanimates. Ultimately, determining the underlying source of the animate processing advantage will require one or more developmental investigations. If New et al. (2007) is correct regarding the evolutionary origin of animate monitoring, then it should be innately specified and observable at early ages. However, if animate monitoring in adults is a result of a gradual accumulation of experience with animates, then children may not show this advantage until enough relevant experience has been accrued. Despite significant interest in the AMH over the last decade, there are to date no tests of this hypothesis with child or infant participants.

What we know already is that elements of animate processing are present at birth. Newborn infants prefer to look at animate (biological) point-light motion over random motion controls (Simion, Regolin, & Bulf, 2008). This component is shared with other vertebrate species, as newborn chicks also show the same preference (Vallortigara, Regolin, & Marconato, 2005). What is more difficult to determine is when a *conceptual* distinction between animate and inanimate entities ultimately develops. Rakison and Poulin-Dubois (2001) provided a rich synthesis of the literature on the animate/inanimate distinction, and highlighted a complex taxonomy of perceptual and cognitive skills that could subserve this development over the first year-and-a half of life. In any case, however, by 3 years of age there is clear evidence for this distinction, when children isolate the most critical feature: that only animates can move by themselves, as a result of some unobservable immanent source (Gelman & Gottfried, 1996).

In the infant literature it is not the animate/inanimate distinction that is typically under investigation, but instead the agent/non-agent distinction (but see Schlottmann & Ray, 2010, for an exception). Agents are typically animates for which the observer infers mental states, such as goals, desires, and beliefs (terms which are missing from the literature on the AMH). Woodward (1998) provided evidence that infants as young as 5–6 months of age can attribute goals to simple human reaching movements. However, when events cue an agentive interpretation, even 3-month-old infants can attribute goals to a novel agent (Luo, 2011; see also Biro & Leslie, 2007; Luo & Baillargeon, 2005). Note that the questions asked in these studies center upon *when* and *how* infants attribute goals. It is only very recently that there is evidence indicating that agentive processing in fact *improves* attention and/or memory for events.

Howard and colleagues (Howard, Riggins, & Woodward, 2019; Howard & Woodward, 2019) have demonstrated that both children and young infants have stronger memory for events that involve agency than those that do not. When young children are exposed to a craft construction sequence, their ability to construct the craft is improved if a human agent was depicted in the sequence compared to the same sequence without a human agent present (Howard et al., 2019). At 9 months of age infants also have more robust memory for a constructed object if it is built by a human hand as compared to a mechanical claw (Howard & Woodward, 2019). However, if infants are given first-hand experience beforehand that the claw is in fact a tool of the agent (and extension of her goal-directed hand), infants memory for the constructed object built by the claw is improved in the same manner as if it was built by a human hand. Although these results are certainly consistent with the AMH, they are also compatible with alternate theories which posit that humans or human actions are prioritized in attention or memory (Bonatti, Frot, Zangl, & Mehler, 2002).

Thus, in the present research we evaluated the AMH with regard to preschool children, sans human stimuli. Our aim in testing preschool children was not to determine whether animate monitoring is innately specified – only evidence from newborns would be definitive on this front. However, such a test is still relevant to the AMH, as null findings at this age would certainly favour a more gradual, experience-based account of the effect, and positive findings would urge one to test with younger populations. In addition, using preschoolers allowed us to test their memory for imitation involving animates, akin to what has been examined in adults (e.g., Nairne et al., 2013). This methodology allows for tight control over experimental stimuli to isolate the activation of a concept of animacy. This obviates concerns about perceptual differences in stimuli, be they static (form) or dynamic (motion).

We report here three experiments; Experiment 1 and 2 serve as supportive experiments leading up to Experiment 3, which provides a strong test of the AMH in preschoolers. Experiment 1 tested a novel imitative memory paradigm with adults, and Experiment 2 used a similar paradigm with 4- and 5-year-olds. In Experiment 2 we also tested whether there were differences in the specific type of animate used, which would favour a more graded representation of animacy in children's minds. Lastly, Experiment 3 served as a critical test of the AMH with preschool children, with the use of identical stimuli across conditions that children were led to believe represented either an animate or inanimate entity. We also included a new kind of control condition, in which children were led to believe that the entity was alive but sessile (inanimate but biological).

2. Experiment 1

In Experiment 1 we tested whether adults recall an action sequence better if it involves a representation of an animate entity than if it involves an inanimate entity. We chose to examine their incidental memory for the event, by exposing them to the sequence without telling them that they would be asked to perform (recall) the sequence later. We hypothesized that adults would have better incidental memory for the event involving the animate in comparison to the one without.

2.1. Methods

2.1.1. Participants

One-hundred University of Regina undergraduates (78 female) received partial course credit for their participation in the experiment. A power analysis with $\alpha = 0.05$ (two-tailed) and power $= 0.80$ indicated that this sample size would be adequate for detecting a medium effect size ($d = 0.57$). Data from one additional participant was collected but replaced as she had prior knowledge of the memory component.

2.1.2. Stimuli

Stimuli included five objects that were displayed on a black foam board. The target entity was either a small grey and white dog[1] or a small grey and white block construct, depending on condition. The four other objects were 1) a green wooden stick, 2) a red tower of plastic blocks, 3) a blue wooden block, and 4) a yellow resin printer spool. The action sequence that was enacted with these objects was: A) tap target with stick three times, B) move target up one side and then down the other side of the tower, C) stamp target on the blue block, and D) circle the spool around the target two times. Stimuli for Experiment 1 are presented in Fig. 1, as part of the broader set of objects used in Experiments 2 and 3. When an object was moved it was always placed back in its home position at the end of the action (including the target).

2.1.3. Design and procedure

Participants were randomly assigned to the dog condition or the block condition. After providing consent, participants were seated at a table across form the experimenter. They began with an incidental exposure to the sequence, in which the experimenter casually asked participants to provide a favour for another member of the lab. They were told that this person was designing a study with children, and wanted adults' opinions on whether the sequence was interesting for children or not. The experimenter then performed the sequence in front of the participant, without any labelling. Participants rated their opinion on numeric scale on a slip of paper, and the experimenter then removed the board and placed it in an adjacent room out of view. They were next told that they would begin the real experiment. They performed a backwards digit span task, and then a spatial memory task with beads. Data from these tasks and from the interest scale are not analyzed further here.

Following these two tasks, the experimenter brought back the board and explained to participants that they were actually interested in their memory for the sequence that they viewed. Participants were asked to perform the sequence as they had observed it, and were filmed while doing so. Participants were then fully debriefed as to the nature of the experiment, and asked not to share any details of the study with any of their friends given the sensitive design.

2.1.4. Scoring

Imitation was scored from video by one primary individual, who was blind to hypotheses. Another individual scored 25 of the videos for reliability purposes. Agreement was high (98%). In all experiments reported here disagreements were resolved through discussion.

Participants were given a score of 1 for each target action that they recalled accurately. A score of 0.5 was assigned to any action with minor deviations (e.g., tapping more or less than three times, climbing up only one side of the tower). Scores of 0 were assigned for any missing actions or any non-target actions.

[1] A small grey and white dog was used in Experiment 1. This dog was subsequently lost, and so a small brown and white dog was used in Experiment 2. Fig. 1 displays only the brown and white dog.

2.2. Results

As hypothesized, participants recalled significantly more target actions in the animate condition ($M = 2.90$, $SD = 0.82$) in comparison to the inanimate condition ($M = 2.32$, $SD = 0.97$), $t(98) = 3.22$, $p < .002$, Cohen's $d = 0.65$.

2.3. Discussion

The results of Experiment 1 are the first to show that memory for sequences of action that involve a representation of an animate entity are recalled more robustly than sequences that do not involve such a representation. This is consonant with Nairne et al. (2013) and Bonin et al. (2014), and most closely with van Buren and Scholl (2017). The novel finding here is that incidental memory for a motor sequence can be affected in this manner. This finding supports the AMH, as initially formulated by New et al. (2007).

Due to the nature of the stimuli there are several alternative explanations for the results of Experiment 1, but for brevity we will only discuss one: that the entities differed perceptually. Because of this observers may have found the dog more visually attractive than the block, and thus were more attentive to what transpired regarding that target. This could be due to specific perceptual features of the dog in relation to the block, or due to the accumulated experience individuals have had with dogs. We deal with this issue directly in Experiment 3. However, the representation itself may also be more interesting on a deeper level simply because of its animate status – an issue which we will leave for the General Discussion.

However, having demonstrated the basic effect in adults with a task that would appeal to children, we next investigated whether young children also process events involving animates differently than those without. No previous research has ever evaluated the AMH with regard to child participants. We also added a new condition that allowed us to explore whether animacy operates as a graded concept in children.

3. Experiment 2

In Experiment 2 we investigated whether 4- and 5-year-old children also recall action sequences involving an animate representation with greater accuracy than a sequence involving an inanimate representation. We utilized the same dog and block conditions from Experiment 1, and also added a beetle condition, in order to compare two types of animates. Our reasoning here was that the beetle may not serve as well as the dog as a representation of an animate in young children's minds (and potentially not in adults' minds), despite the fact that both move autonomously. Most adults view invertebrates with a sense of fear, aversion, or antipathy (Kellert, 1993). Jipson, Labotka, Callanan, and Gelman (2018) found that in discussions about animals with their children, parents use less "animate" pronouns ("he", "she", etc.) and more "inanimate" pronouns (e.g., "it") when talking about bees relative to non-mammalian vertebrates (e.g., fish). Adults and children also treat a starfish differently than a chinchilla in a variety of ways that relate to a concept of animacy (Jipson & Gelman, 2007).

Two other notable changes from Experiment 1 were that children observed a six-step sequence, and were now told in advance that they would be seeing the sequence board again and would have a turn with it (hinting at recall). We were not entirely certain whether children would have strong enough recall of the sequence if they were not told this, and wanted to avoid floor effects. However, after piloting with $n = 20$ children with the four-step sequence, we became concerned instead about a ceiling effect. Thus two additional actions were added.

As in Experiment 1, we hypothesized that recall would be superior in the dog condition relative to the inanimate condition. We did not specifically hypothesize that recall in the beetle condition would be superior to the block or inferior to the dog, but did predict that performance would fall between these two conditions.

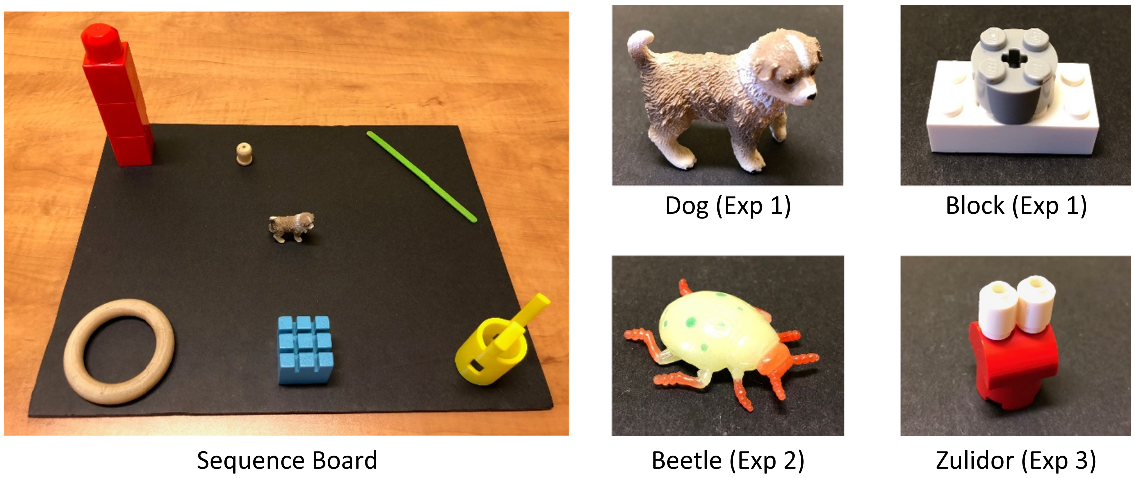

Fig. 1. The stimuli used in all experiments. Note that only 4 objects were used with adults, while 6 were used with children. The dog is shown on the board to illustrate the home position of the target.

3.1. Method

3.1.1. Participants

Sixty 4- and 5-year-old children (36 female, 38 4-year-olds) were recruited. Participants were recruited from local daycares in Regina, Saskatchewan, and the surrounding area and tested at the daycare. A power analysis with $\alpha = 0.05$ and power $= 0.80$ indicated that this sample size was underpowered, as it would only be adequate for detecting a large effect size ($f = 0.40$). However, this was the sample size we were able to recruit during the specific time frame we had allotted. Children were randomly assigned to the dog condition ($n = 20$), beetle condition ($n = 19$), or block condition ($n = 22$). An additional seven children were sampled but excluded for the following reasons: failing to perform any actions with the board ($n = 7$), and poor attention during the demonstration phase ($n = 1$). Parents provided consent ahead of time, and children were compensated with a small toy at the end of the study (approximate value $5).

3.1.2. Stimuli

Stimuli included seven objects that were presented on a black foam board. The target entities were now either the dog from Experiment 1, a small plastic beetle, or the block construct from Experiment 1. The remaining six objects were: the same four objects used in Experiment 1, a wooden ring, and a small red wooden bead. The sequence was now: A) tap target with stick three times, B) move target up one side of the tower and down the other side, C) place ring over target, twist it, and remove it, D) use target to push the bead to one side and then back, E) stamp target on block, and F) circle target with spool two times.

3.1.3. Design and procedure

Children were seated at a table across form the experimenter. The sequence board was brought out, and the experimenter told the child "I'm going to show you something. I want you to watch carefully, so that you can do what I do later." The sequence was then demonstrated, and then put away, out of sight. The experimenter and the child then read a short picture book (that did not involve any animals). Following this, the board was brought back, and the experimenter said: "Now it's your turn - can you do what I did with these?" If a child asked questions regarding the actions, a neutral response was given (e.g., "It's your turn").

Children in the beetle condition only were also asked two additional questions after the recall phase: 1) "Do you think bugs are cool or yucky?", and 2) "Do you think bugs are scary?" Our aim here was to see if children's attitudes about insects related to their memory. For the sake of brevity, we do not report analyses regarding these questions, as there were no significant associations.

3.1.4. Scoring

The scoring procedure was identical to Experiment 1. Agreement was again high between scorers (95%).

3.2. Results

Mean recall scores for each condition can be found in Fig. 2. A one-way ANOVA on recall scores revealed a significant main effect of condition, $F(2,57) = 3.62$, $p = .033$, $\eta^2 = 0.11$. Post-hoc Tukey's tests revealed that the dog condition was, as hypothesized, significantly higher than the block condition ($p = .025$), and that the beetle condition was not significantly different from either of the other two conditions (both $ps > 0.359$).

3.3. Discussion

The results of Experiment 2 indicate that young children, like adults, recall an action sequence involving a dog – representing an animate – more robustly than an action sequence involving a block. This is the first evidence to support the AMH in young children. Because 4- and 5-year-olds have already gained considerable experience with the animate/inanimate distinction (Gelman & Gottfried, 1996), these results do not indicate that increased animate monitoring is innate. But at the very least they indicate that it is relatively early emerging.

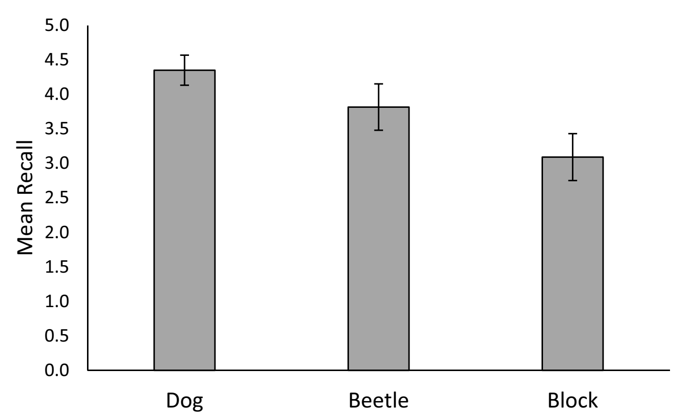

Fig. 2. Mean recall scores across conditions in Experiment 2. Error bars represent standard error.

However, these results hint at the possibility that not all animates hold equal status in the minds of young children. The dog was clearly a higher value target than the block, but the beetle was not unequivocally so, holding tenure between the dog and block.[2] It may be that, being an insect/arthropod/invertebrate, the beetle is a lower status animate than the dog, which is a mammal/vertebrate. This may be because children's representation of animates is based on a human template, and the beetle differs from this template to a greater degree than the dog (Carey, 1985), or because Western children have acquired a cultural belief that insects should be undervalued relative to other animals (Kellert, 1993). Indeed, either of these possibilities may relate to why parents talk about insects differently with their children (Jipson et al., 2018), and this linguistic covariation may strengthen the distinction. However, more research will ultimately be necessary to pin down the source of this difference. In ongoing related research our lab is investigating whether adults' attention to mammals is greater than their attention to non-mammals.

The conclusions we have drawn above regarding the dog and the block are unfortunately susceptible to the same alternative explanation that plagued Experiment 1: children may have simply found the dog more visually appealing than the block construct, and thus encoded the actions involving this target with relatively higher fidelity. We now turn our attention to this critical issue in Experiment 3.

4. Experiment 3

The main goal of Experiment 3 was to demonstrate that it is the animate status of an entity per se that engenders increased attention and stronger encoding, and not its perceptual features. To this end, we created a single block construct that was used in all conditions, and what differed was only what children were told about what this construct represented. In the *animate* condition children were told that the construct represented a novel marine animal that locomotes, similar to a crab or sea slug.

Given the results of Experiment 2, we opted to include two types of inanimate conditions to compare the animate condition against. In the *sessile* condition, children were told that the construct represented a novel marine animal that does not locomote, similar to a coral or barnacle. This condition controls for the possible heightened interest children may have in any entity that is described as a living thing, but which does not possess clear animate characteristics. In the *rock* condition, children were told the construct represented a rare marine mineral. This condition was very clearly inanimate, similar to the block conditions used in the previous two experiments.

Two additional minor differences from Experiment 2 were that children were tested in a university lab setting instead of in a daycare setting, and that only 4-year-old children were sampled.

4.1. Method

4.1.1. Participants

Sixty-nine 4-year-old children (37 female) were recruited (M_{age} = 4.39 years, *range* = 4 years 0 months–4 years 10 months). All children were typically developing and from the area surrounding Regina, Saskatchewan. Participants were recruited from a computerized database maintained by the first author. A power analysis with $\alpha = 0.05$ and power = 0.80 indicated that this sample size would be adequate for detecting the observed effect size from Experiment 2 ($f = 0.39$). Equal numbers of children ($n = 23$) were randomly assigned to each condition. An additional 18 children were sampled but dropped for the following reasons: failing to perform any actions with the board ($n = 9$), poor attention during the demonstration phase ($n = 4$), parental interference (n = 2), and experimenter error ($n = 3$). Parents were compensated with $5, and children with a small toy (approximate value $5).

4.1.2. Stimuli

The target object was a red and white block construct (see Fig. 1). All other items on the board and their associated actions were identical to Experiment 2. Two images were also shown to participants in the preamble: a red and white nudibranch photographed head-on, and a picture of the deep ocean (under the surface, only showing water). These were used to enrich children's prior knowledge about the entity.

4.1.3. Design and procedure

Children were seated across the table from the experimenter. The experimenter then told children information about “(a) zulidor”, using the two images as props. The information differed according to condition, and these details can be found in Appendix A. For the animate and sessile conditions, the basic elements of the information were similar (that zulidors are living things that reside in the ocean, acquire food, are preyed upon, etc.). For the rock condition, many details diverged from the animal versions, naturally (including mass noun syntax). However, the word count was identical across conditions, and each contained approximately the same number of propositions. For the animate condition the experimenter gestured an act of swimming using the nudibranch image when describing the zulidor's movement, and for the sessile condition the experimenter gestured an absorbing motion (opening and contracting her hand) over the top of the nudibranch image while describing the zulidor's food intake process. No such gesturing was used in the rock condition.

After this preamble, children were shown the block zulidor and told “And this is also (a) zulidor, just like this (one) here [pointing at nudibranch image]. And I'm going to show you something using this zulidor.” The board and objects were then brought out, and the experimenter told the child to watch carefully as in Experiment 2. The sequence was then demonstrated, and then put away. The child then completed the NIH Toolbox Picture Vocabulary Test (PVT) on an iPad (this data not analyzed here). Following this, the board was brought back and the experimenter asked the child: “Can you do what I did with the zulidor?” Neutral responses were provided if children asked questions during the response period.

4.1.4. Scoring

The scoring procedure was identical to Experiment 1. Agreement was again high between scorers (97%).

4.2. Results

Mean recall scores for each condition can be found in Fig. 3. A one-way ANOVA on recall scores revealed a significant main effect of condition, $F(2,66) = 4.58$, $p = .014$, $\eta^2 = 0.12$. Tukey's tests revealed that the animate condition was significantly higher than the sessile condition ($p = .019$), and the rock condition ($p = .047$), and that the sessile and rock conditions were not significantly different from each other, ($p > .93$).

4.3. Discussion

The results of Experiment 3 definitively indicate that involving an animate in an action sequence improves children's memory for that sequence relative to an inanimate. These results are especially impressive given the fact that this particular animate was entirely novel to children, and thus children had no extensive experience with it moving autonomously in the world. It was enough simply to tell them that this creature does indeed move, eat, think, and reproduce, like all other animals. This suggests that it is the activation of a deeper concept of

[2] Admittedly with larger sample sizes the beetle average could possibly be significantly higher than the block average. However, in this case it might also be significantly lower than the dog condition.

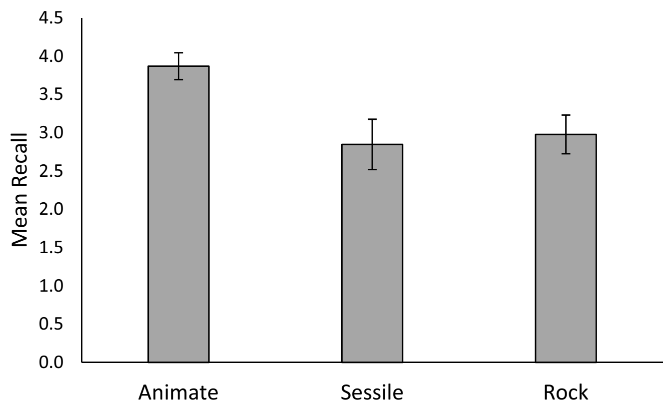

Fig. 3. Mean recall scores across conditions in Experiment 3. Error bars represent standard error.

animacy that drives enhanced attention and recall.

These results also indicate that telling children that something is alive is insufficient at enhancing their memory for action involving that thing. Indeed, performance in the sessile condition was similar to performance in the rock condition and the block condition in Experiment 2. Children in this condition were told that the zulidor was a living thing, but in the next breath told that they do not move. Young children do not typically extend the concept ALIVE to nonmoving life forms, such as plants (Opfer & Siegler, 2004), so children were probably impervious to this proposition. It should be noted that while we believe that non-locomotion was probably the critical difference between these conditions, it is difficult to know for certain, as there were additional differences in the language between these two conditions. The present results are the first to show that when the same object is treated as clearly animate or less so this has implications for how well children recall events involving that object.

It should be noted that recall was, on average, lower in the animate condition compared to the dog condition in Experiment 2 (by about half a target action). While it is tempting to conclude that children's preference for, or experience with, the dog boosts performance further, it is impossible to be certain. Children engaged in a more cognitively demanding distractor task in the present study (the PVT) relative to Experiment 2 (being read a storybook), and were also tested in an unfamiliar location (a lab) relative to Experiment 2 (their daycare); Both of these properties could have hampered recall. Future studies can address with more clarity the roles that familiarity and novelty play in children's animate monitoring.

5. General discussion

Animals need to pay close attention to other animals in their environment, regardless of whether they are predators or prey, and humans are but one animal among many whose livelihood depended upon this ability. While previous research has shown that adult humans display heightened attention to animates relative to inanimates (Calvillo & Jackson, 2014; Jackson & Calvillo, 2013; New et al., 2007; Pratt et al., 2010; Scholl & Gao, 2013; Yang et al., 2012) and better memory for animates over inanimates (Bonin et al., 2014; Nairne et al., 2017; van Buren & Scholl, 2017; VanArsdall et al., 2013), the present results are the first to show that preschool-aged children have more robust memory for events involving animates. Experiment 1 provided novel evidence that adults recall more actions in an event if it involves an animate entity relative to an inanimate entity. Experiment 2 demonstrated that children show this same memory advantage for animates in their event memory, and also revealed that there may be less of an advantage for certain animates (e.g., beetle/insect/invertebrate) compared to others (dog/mammal/vertebrate). Experiment 3 clarified the results of the first two experiments to show that the animate memory advantage is the result of children's construal that an entity is an animate, and is not due to children's extensive history with an animate or the detection of specific static or dynamic visual features. This experiment also demonstrated that children's construal that something is alive is insufficient for providing a memory advantage; the advantage is only for animates per se.

These results are the first of their kind in support of the AMH in young children. New et al. (2007) proposed that increased animate monitoring was a product of the evolution of *Homo sapiens*. Construed as such, it must not be the result of an individual human's experience with animates and inanimates in the world, but must instead be either innate or an emergent property of related innate tendencies. Despite great interest in this hypothesis over the last 12 years, there have been no developmental investigations of this nature. The present results indicate that if animate monitoring is a result of experience it can develop in relatively short order, and does not require extensive experience. However, it will take novel paradigms with infants to provide evidence for innate animate monitoring.

Evidence in support of the AMH based on attentional paradigms that use static real-world animates have recently been questioned, as these paradigms may instead measure perceptual differences between animates and inanimates rather than attentional differences (Hagen & Laeng, 2016, 2017). However, evidence does indicate that abstract animate *motion* captures attention better than inanimate motion (Pratt et al., 2010; Scholl & Gao, 2013), and that a deeper concept of animacy improves memory (Nairne et al., 2013). The present results are the first to show that nonverbal memory for real world events is also improved when animates are present. Using this specific methodology allowed us to compare adults with children, and demonstrate that the same memory advantage exists at both ages. Experiments 1 and 2 on their own would be insufficient to provide support for the AMH, as visual differences between the stimuli could account for the memory advantage. However, Experiment 3 used identical visual stimuli and replicated the same basic effect. These results are similar in some ways to Cogdill (2015), who showed enhanced verbal memory for objects that were touched by an animate relative to an inanimate. The actions used in the present study bear some resemblance to touching actions, though they were more complex in semantic roles (sometimes the animate was the agent, sometimes the patient) and manners of motion.

Although Experiment 3 dealt with visual differences which could lead to differences in attention or encoding, it did not deal with possibility that the deeper concept of animacy may be a more interesting or engaging concept than that which encompasses inanimates. Even when an animate is not currently moving it always possesses the possibility for dynamic action. This ever-present unpredictability may be what makes animate motion more salient than inanimate motion (e.g., Pratt et al., 2010), and adults' and children's accumulated experience with such motion may lead to increased interest in anything that is categorized as animate. However, this begs the question of why a beetle should be any less interesting than a dog, as hinted at by Experiment 2, since they should be similarly unpredictable in this sense. It is important to note, however, that the non-significant differences we observed with the beetle are speculative at best; This result needs replication with two animals that are more closely matched on familiarity.

Despite the strengths of Experiment 3 there are complexities associated with the design which will require further investigation. First, because we told children that they would be asked to imitate the sequence later, their memory was explicit in nature. As such, the processes they utilized to remember the event may have differed between the conditions (e.g., potentially different verbal encoding). An implicit test of memory would provide stronger evidence for the automatic deployment of attentional enhancements for the animate entity. Perhaps children could learn about a novel method of performing an action as it pertains to an animate or an inanimate entity. Later, children could be faced with a situation in which the novel action method would be beneficial at solving a problem, and observe potential differences in its execution.

Second, we did not include any condition in which the zulidor was an inanimate but moving entity, and thus animacy was confounded with movement. It is difficult to generate situations in which inanimate entities move for which observers would not automatically assume animacy. For example, if told that the zulidor was a submarine, observers of all ages might either assume that it is in fact animate (e.g, "It can talk too - it's just pretend!") or that an animate third party is generating the motion (e.g., a driver inside or someone controlling it remotely). Perhaps a future study might describe a slow moving purple slime that is oozing out of a jar as being either some slime that was accidentally spilled over or as an escaping animate slime creature. But of course details would need to be worked out in order to make the former condition as interesting as the latter.

An important question has yet to be addressed in both the animate monitoring literature and the infant goal understanding literature: What is the difference between agency and animacy for memory enhancements? The present results are concordant with research showing that children and infants have better recall for events which involve a human agent (Howard et al., 2019; Howard & Woodward, 2019). One could construe the human in those studies as merely an animate being, and one could equally well construe the dog and the animate zulidor in the present studies more richly as agents. Any study of animate monitoring could in principle be relabeled as a study of agentive monitoring, though in these studies (with the exception of animate motion) agency is not directly perceivable, but instead is either wrapped up in the semantics of a word or is inferred from perceptual input. It is possible that the reduced mnemonic advantage displayed for the beetle is the result of agentive differences, as insects are typically considered by adults to be less mentally autonomous than most vertebrates (see the rich debate associated with Barron & Klein, 2016). However, there is no reason to believe that preschool children hold these beliefs, and potentially more reason to doubt that they do (given limited theory of mind abilities at this age). It is interesting to note that the human agent memory advantage also exists in a variety of non-human primates (Howard, Festa, & Lonsdorf, 2018; Howard, Wagner, Woodward, Ross, & Hopper, 2017). Despite the likely presence of animate monitoring in other animals, especially primates, there have been no similar tests of the AMH in any animal other than the human.

Understanding the relative importance of animacy and agency in these effects is important in terms of developing hypotheses about origins. The origins of goal understanding in infancy are a matter of some debate, with some proposing an innate propensity to identify and process the actions of any agent, regardless of form (Biro & Leslie, 2007; Gergely, Nádasdy, Csibra, & Bíró, 1995; Luo, 2011; Premack, 1990), and others arguing for a more experiential account, based on human behavior and infants' own goal-directed behavior (Filippi & Woodward, 2016; Gerson & Woodward, 2014; Woodward, 2009). The origins of animate *detection* on the basis of motion are certainly less ambiguous, as infants (both human and chicken) show an innate preference for biological point-light motion (Simion et al., 2008; Vallortigara et al., 2005). If an inborn preference for biological motion leads to greater attention paid to it in the real world, then this could very well serve as the basis for greater attention to static and conceptual animates later in life. However, we do not know if pairwise preferences in the lab relate to real-world attention in human infants. Further research and/or theoretical development is necessary to clarify these issues.

In short, the present results indicate that both adults and preschool-aged children recall with greater fidelity events that involve an animate over those that involve an inanimate. They pave the way for further investigations with younger participants, open the door to future research on possible graded representations of animacy, and call for theoretical clarity on the roles of agency and animacy in attention and memory, in both humans and other animals.

CRediT authorship contribution statement

Jeff Loucks:Conceptualization, Formal analysis, Methodology, Resources, Supervision, Writing - original draft, Writing - review & editing.**Kaitlyn Verrett**:Project administration, Writing - review & editing.**Berit Reise**:Project administration, Writing - review & editing.

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Appendix A. Preamble for each condition of Experiment 3

Animate

This here is a zulidor. Zulidors are very interesting creatures that live far out in the ocean. They are fast, and are pretty smart. They crawl around and gobble up little animals that are smaller than them, and sometimes they eat plants. Fish like to eat zulidors. They only live for about a month, but like all animals can make baby zulidors.

Sessile

This here is a zulidor. Zulidors are very interesting things that live far out in the ocean. They don't move, and are very odd looking. They grow attached to rocks, and absorb bits of plant and animal matter that pass near them. Fish like to eat zulidors. They only live for about a month, but have the ability to make new zulidors.

Rock

This here is zulidor. Zulidor is a very interesting kind of rock that is only found in the ocean. It is found at the bottom and is very pretty looking. It is harder than sand, but not as hard as a diamond. Fish sometimes make their homes around zulidor. It's hard for people to find, but people make jewelry out of it.

References

Barron, A. B., & Klein, C. (2016). What insects can tell us about the origins of consciousness. *Proceedings of the National Academy of Sciences, 113*(18), 4900. https://doi.org/10.1073/pnas.1520084113.

Biro, S., & Leslie, A. M. (2007). Infants' perception of goal-directed actions: Development through cue-based bootstrapping. *Developmental Science, 10*(3), 379–398. https://doi.org/10.1111/j.1467-7687.2006.00544.x.

Bonatti, L., Frot, E., Zangl, R., & Mehler, J. (2002). The human first hypothesis: Identification of conspecifics and individuation of objects in the young infant. *Cognitive Psychology, 44*(4), 388–426. https://doi.org/10.1006/cogp.2002.0779.

Bonin, P., Gelin, M., & Bugaiska, A. (2014). Animates are better remembered than inanimates: Further evidence from word and picture stimuli. *Memory & Cognition; New York, 42*(3), 370–382.

Calvillo, D. P., & Hawkins, W. C. (2016). Animate objects are detected more frequently than inanimate objects in inattentional blindness tasks independently of threat. *The Journal of General Psychology, 143*(2), 101–115. https://doi.org/10.1080/00221309.2016.1163249.

Calvillo, D. P., & Jackson, R. E. (2014). Animacy, perceptual load, and inattentional blindness. *Psychonomic Bulletin & Review, 21*(3), 670–675. https://doi.org/10.3758/s13423-013-0543-8.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge, MA: MIT Press.

Cogdill, M. (2015). *Evidence for a mnemonic benefit of animate-object interaction: Enhanced retention from animate contact* (Unpublished Masters Thesis)West Lafayette, IN: Purdue University.

Filippi, C. A., & Woodward, A. L. (2016). Action experience changes attention to kinematic cues. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.00019.

Gao, T., McCarthy, G., & Scholl, B. J. (2010). The wolfpack effect: Perception of animacy irresistibly influences interactive behavior. *Psychological Science, 21*(12), 1845–1853.

https://doi.org/10.1177/0956797610388814.
Gelman, S. A., & Gottfried, G. M. (1996). Children's causal explanations of animate and inanimate motion. *Child Development, 67*(5), 1970–1987. https://doi.org/10.2307/1131604.
Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*(2), 165–193. https://doi.org/10.1016/0010-0277(95)00661-H.
Gerson, S. A., & Woodward, A. L. (2014). Learning from their own actions: The unique effect of producing actions on infants' action understanding. *Child Development, 85*(1), 264–277. https://doi.org/10.1111/cdev.12115.
Guerrero, G., & Calvillo, D. P. (2016). Animacy increases second target reporting in a rapid serial visual presentation task. *Psychonomic Bulletin & Review, 23*(6), 1832–1838. https://doi.org/10.3758/s13423-016-1040-7.
Hagen, T., & Laeng, B. (2016). The change detection advantage for animals: An effect of ancestral priorities or progeny of experimental design? *I-Perception, 7*(3), https://doi.org/10.1177/2041669516651366.
Hagen, T., & Laeng, B. (2017). Animals do not induce or reduce attentional blinking, but they are reported more accurately in a rapid serial visual presentation task. *I-Perception, 8*(5), https://doi.org/10.1177/2041669517735542.
Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *The American Journal of Psychology, 57*(2), 243–259. https://doi.org/10.2307/1416950.
Howard, L. H., Festa, C., & Lonsdorf, E. V. (2018). Through their eyes: The influence of social models on attention and memory in capuchin monkeys (Sapajus apella). *Journal of Comparative Psychology, 132*(2), 210–219. https://doi.org/10.1037/com0000111.
Howard, L. H., Riggins, T., & Woodward, A. L. (2019). Learning from others: The effects of agency on event memory in young children. *Child Development*. https://doi.org/10.1111/cdev.13303.
Howard, L. H., Wagner, K. E., Woodward, A. L., Ross, S. R., & Hopper, L. M. (2017). Social models enhance apes' memory for novel events. *Scientific Reports, 7*(1), 1–7. https://doi.org/10.1038/srep40926.
Howard, L. H., & Woodward, A. L. (2019). Human actions support infant memory. *Journal of Cognition and Development, 0*(0), 1–18. https://doi.org/10.1080/15248372.2019.1664549.
Jackson, R. E., & Calvillo, D. P. (2013). Evolutionary relevance facilitates visual information processing. *Evolutionary Psychology, 11*(5), https://doi.org/10.1177/147470491301100506 (147470491301100500).
Jipson, J. L., & Gelman, S. A. (2007). Robots and rodents: Children's inferences about living and nonliving kinds. *Child Development, 78*(6), 1675–1688. https://doi.org/10.1111/j.1467-8624.2007.01095.x.
Jipson, J. L., Labotka, D., Callanan, M. A., & Gelman, S. A. (2018). How conversations with parents may help children learn to separate the sheep from the goats (and the robots). In M. M. Saylor, & P. A. Ganea (Eds.). *Active Learning from Infancy to Childhood: Social Motivation, Cognition, and Linguistic Mechanisms* (pp. 189–212). . https://doi.org/10.1007/978-3-319-77182-3_11.
Kellert, S. R. (1993). Values and perceptions of invertebrates. *Conservation Biology, 7*(4), 845–855 (Retrieved from JSTOR).
Luo, Y. (2011). Three-month-old infants attribute goals to a non-human agent. *Developmental Science, 14*(2), 453–460. https://doi.org/10.1111/j.1467-7687.2010.00995.x.
Luo, Y., & Baillargeon, R. (2005). Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. *Psychological Science, 16*(8), 601–608 (Retrieved from JSTOR).
Nairne, J. S., VanArsdall, J. E., & Cogdill, M. (2017). Remembering the living: Episodic memory is tuned to animacy. *Current Directions in Psychological Science, 26*(1), 22–27. https://doi.org/10.1177/0963721416667711.
Nairne, J. S., VanArsdall, J. E., Pandeirada, J. N. S., Cogdill, M., & LeBreton, J. M. (2013). Adaptive memory: The mnemonic value of animacy. *Psychological Science, 24*(10), 2099–2105. https://doi.org/10.1177/0956797613480803.
New, J., Cosmides, L., & Tooby, J. (2007). Category-specific attention for animals reflects ancestral priorities, not expertise. *Proceedings of the National Academy of Sciences, 104*(42), 16598–16603. https://doi.org/10.1073/pnas.0703913104.
Opfer, J. E., & Siegler, R. S. (2004). Revisiting preschoolers' living things concept: A microgenetic analysis of conceptual change in basic biology. *Cognitive Psychology, 49*(4), 301–332. https://doi.org/10.1016/j.cogpsych.2004.01.002.
Pratt, J., Radulescu, P. V., Guo, R. M., & Abrams, R. A. (2010). It's alive!: Animate motion captures visual attention. *Psychological Science, 21*(11), 1724–1730. https://doi.org/10.1177/0956797610387440.
Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition, 36*(1), 1–16.
Rakison, D. H., & Poulin-Dubois, D. (2001). Developmental origin of the animate-inanimate distinction. *Psychological Bulletin, 127*(2), 209–228. https://doi.org/10.1037/0033-2909.127.2.209.
Schlottmann, A., & Ray, E. (2010). Goal attribution to schematic animals: Do 6-month-olds perceive biological motion as animate? *Developmental Science, 13*(1), 1–10.
Scholl, B. J., & Gao, T. (2013). Perceiving animacy and intentionality: Visual processing or higher-level judgment? In M. D. Rutherford, & V. A. Kuhlmeier (Eds.). *Social perception: Detection and interpretation of animacy, agency, and intention* (pp. 197–229). US: MIT Press.
Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences, 105*(2), 809–813. https://doi.org/10.1073/pnas.0707021105.
Vallortigara, G., Regolin, L., & Marconato, F. (2005). Visually inexperienced chicks exhibit spontaneous preference for biological motion patterns. *PLoS Biology, 3*(7), e208. https://doi.org/10.1371/journal.pbio.0030208.
van Buren, B., & Scholl, B. J. (2017). Minds in motion in memory: Enhanced spatial memory driven by the perceived animacy of simple shapes. *Cognition, 163*, 87–92. https://doi.org/10.1016/j.cognition.2017.02.006.
VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N. S., & Blunt, J. R. (2013). Adaptive memory: Animacy processing produces mnemonic advantages. *Experimental Psychology, 60*(3), 172–178. https://doi.org/10.1027/1618-3169/a000186.
Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*(1), 1–34. https://doi.org/10.1016/S0010-0277(98)00058-4.
Woodward, A. L. (2009). Infants' grasp of others' intentions. *Current Directions in Psychological Science, 18*(1), 53–57. https://doi.org/10.1111/j.1467-8721.2009.01605.x.
Yang, J., Wang, A., Yan, M., Zhu, Z., Chen, C., & Wang, Y. (2012). Distinct processing for pictures of animals and objects: Evidence from eye movements. *Emotion (Washington, D.C.), 12*(3), 540–551. https://doi.org/10.1037/a0026848.