Accepted for publication in Journal of Experimental Child Psychology

Prepotency in action: Does children's knowledge of an artifact affect their ability to inhibit acting on it?

Andrew Simpson

Department of Psychology, University of Essex

Daniel J. Carroll

Department of Psychology, University of Sheffield

Kevin J. Riggs

Department of Psychology, University of Hull

Email: K.Riggs@hull.ac.uk

Abstract

Prepotent actions are actions that are strongly triggered by the environment, and so tend to be carried out, unless intentionally avoided. Understanding what makes an action prepotent is central to an understanding of inhibitory control. The current study investigated actions made on artifacts, since in artifact-dense cultures, much everyday behavior is focused them. Eighty 3-year-olds were tested on a Go/no-go task that required children to make an action on go trials, and to withhold it on no-go trials. These actions were made on artifacts with which the actions were either associated (e.g., drawing with a crayon) or unassociated (e.g., drawing with a hammer). Failure to avoid the go action on no-go trials was taken as evidence that the action was prepotent. Results suggested that an action did not need to be associated with an artifact in order for it to be prepotent (so drawing with a hammer could be prepotent). However, associated actions were sometimes produced even when children had been instructed to make an unassociated action. Children sometimes drew with a crayon when told to hammer with it, but never hammered when told to draw.

Word count: 3,708 (including references)

Key words: development, inhibitory control, prepotency, artifact, action.

Introduction

When is inhibitory control needed to stop an action? The consensus view from cognitive psychology seems to be that inhibitory control is needed when an automatically triggered action is incompatible with current goals. Many of the automatic responses we make are perfectly appropriate to our situation – such as turning a handle to open a door. Being able to automatize frequently used actions benefits cognitive efficiency. However, actions that are triggered automatically run the risk of being in conflict with current goals, and will require inhibitory control to stop them. Such automatically triggered actions are said to be 'prepotent'. Thus, the need for inhibition to control action often depends on the inappropriate triggering of prepotent responses. It is clear, therefore, that understanding prepotency is an integral part of building an explanatory account of how inhibitory control, and the executive system more generally, develops (Simpson, Riggs, Beck, Gorniak, Abbott & Diamond, 2012).

In the research reported here, we investigate the prepotency of manual actions made on artifacts (i.e., manufactured objects). This kind of action is important because, in artifact-dense cultures, much everyday behavior is made on artifacts. As such, they provide a valuable opportunity to investigate inhibitory control under conditions that pertain in everyday life, and can complement the short-term stimulus-response associations set up in many laboratory investigations of inhibition. Actions on artifacts typically involve learned associations built up over time. Most artifacts are associated with a specific action, related to the artifact's function: for example, a cup is associated with the specific action |*grasp by handle and lift to mouth*|. A key question is whether these artifact-specific associations influence prepotency in children (Barrett, Davis & Needham, 2007; Simpson & Riggs, 2007). The current study investigates whether actions that are associated with an artifact's function are more prepotent than other, unassociated actions.

One previous study has investigated artifact-action prepotency, using the Box-search task, an object-based variant of the Go/no-go paradigm (Simpson & Riggs, 2007). Children were shown a series of boxes, and were told to open boxes with one type of cue on the lid (go trials) and to leave shut boxes with another type of cue (no-go trials). Go-trial boxes contained stickers, which children could keep. Inappropriate go responses made on no-go trials were assumed to reflect a failure to inhibit a prepotent go action. Simpson and Riggs (2007) argued that opening a box is prepotent in the box-search task because of the learned association between boxes and opening. They proposed that, because of this association, activating the perceptual representation of a box leads to some activation of the motor representation for opening.

Support for the proposal that artifact-action associations underlie prepotency came from a comparison of two versions of the Box-search task (Experiment 2, Simpson & Riggs, 2007). In the (standard) Habitual condition, children performed the action associated with boxes on go trials (they opened boxes), whereas in the Novel condition, they performed an action unassociated with boxes (they put a hoop over boxes for the experimenter to open). In the Habitual condition, 3-year-olds erred on about 50% of no-go trials (i.e., they opened boxes). In contrast, in the Novel condition, children erred on just 10% of no-go trials; and these errors involved opening boxes, not putting hoops over them. The fact that children never put hoops over boxes on no-go trials suggested that only the specific action associated with boxes (i.e., opening them) was prepotent in the task. In other words, only the action associated with the artifact generated prepotent responses. It was also found that prepotency on this task was not affected by the presence of a reward (Experiment 3, Simpson & Riggs, 2007). In the Box-search task, the consequence of opening boxes on a go trial was to win a sticker (which only the go boxes contained). However, children made equal numbers of box-opening errors on no-go trials, irrespective of whether they received a sticker on go trials. Thus, children were not more likely to respond on no-go trials when making that response was rewarded on go trials. Overall, the prepotency of the to-be-inhibited response appeared to be determined by an artifact-action association, and not by the presence of a reward.

We suggest three reasons to question the Box-search methodology. First, in the Box-search task, the unassociated action was to place a hoop over the boxes. Holding the hoop may have prevented children from box-opening – it is harder to open a box when you are holding a hoop. It is possible, therefore, that children would have opened more boxes in the Novel condition if a different unassociated action were used – one in which they were not holding another object. Second, using the hoop in the Novel condition also introduced a second kind of artifact to the Box-search task (in addition to the boxes). We do not know what the effect of this second artifact was. It could have further reduced children's tendency to open boxes by attracting their attention away from the boxes and towards the hoop. And third, it is possible that the hoop-over action used in the Box-search task is a 'special case', that is not typical of most unassociated actions. Beck, Carroll, Brunsdon and Gryg (2011) have suggested that when children use an unfamiliar method to select a response (such as pointing with an arrow), it leads to more accurate responding. They suggest that children are less impulsive (i.e., think more about what to do) when acting in this way, and so are more likely to respond correctly. It is possible that children made no hoop-over errors in the Box-search task because they were less impulsive when using this unfamiliar method to select responses. Thus the Box-search data may not tell us whether unassociated actions are, in general, less prepotent than associated actions.

Currently then, the proposal that artifact-action associations underlie prepotency rests on the finding that children make more no-go errors in the associated-action than unassociated-action versions of the Box-search task (Simpson & Riggs, 2007). However, we suggest that the choice of unassociated action makes this finding difficult to interpret. In the present study, we sought a more reliable test of whether learned associations modulate the prepotency of actions made on artifacts. Children were tested on a new variant of the Go/no-go task (the Artifact Go/no-go task) that manipulated the *relation* between an artifact and action. There were two conditions: In the Associated condition, the artifact and action were associated (e.g., a crayon and the action of drawing). In the Unassociated condition, there was no association between artifact and action (e.g., a crayon and the action of hammering). If artifact-action associations modulate prepotency, then no-go accuracy should be: (i) low in the Associated condition, because seeing the crayon should trigger the associated action of drawing; and (ii) high in the Unassociated condition, because seeing the crayon should not trigger the unassociated action of hammering. If, on the other hand, this relation does not modulate response prepotency, then manipulating the pairing of artifact and action should have no effect on no-go accuracy.

The Artifact Go/no-go task improved on the Box-search task in three ways. First, unlike the Box-search task, there is no ‘second artifact’ (i.e., no hoop) in the Unassociated condition of the Artifact Go/no-go task. A single artifact was used on each trial with both the Associated and Unassociated condition of the Artifact Go/no-go task. Second, in the Box-search task, different actions were used in the Habitual and Novel conditions. Simpson and Riggs (2007) assumed that what made children perform differently in the two conditions was that the opening action was associated with a box (in the Habitual condition), and the hoop-over action was not (in the Novel condition). However, it may be some other property that distinguished the two actions. This may have been the case if, for example, children were less impulsive when selecting boxes using the hoop than when opening them directly (Beck et al., 2011). In the Artifact Go/no-go task the *same* action is used in the Associated and Unassociated conditions; what changes is the artifact with which it is made. Third, in the Artifact Go/no-go task it was possible to test a range of artifacts rather than just one (the box in the Box-search task). We tested four artifacts – a mobile phone, handled cup, hammer and crayon – having first checked that young children knew the associated action for each.

In the Artifact Go/no-go task, children were presented sequentially with examples of a single artifact kind (e.g., a series of crayons). If the item was colored blue, the child was to make a go response, and if it was colored red, the child was to make no response. Each child completed two conditions: the Associated condition (e.g., drawing with a crayon) and the Unassociated condition (e.g., lifting a cup to the ear). Each condition comprised four practice trials followed by sixteen test trials. The artifacts and actions were arranged in four counterbalanced combinations, shown in Table 1. This ensured that they were used equally often in the Associated and Unassociated conditions.

Method

Participants. Eighty children (39 girls and 41 boys) participated in the study. Children were aged between 3;0 and 3;8 (mean age 3;4). All children attended nurseries in a semi-rural county of England, spoke English as a first language, and none had behavioral or educational problems. The majority of children were white and from a middle-class background.

Design. A repeated-measures design was used. The independent variables were Trial type (Go, No-go) and Artifact-action relation (Associated, Unassociated). Dependent variables were accuracy and error type (associated versus unassociated errors).

Table 1. The four artifact-action combinations used in the Artifact Go/no-go task. Each artifact and action was used in one Associated and one Unassociated condition.

Artifact-action combination	Associated condition	Unassociated condition
1	lift phone to ear	draw on paper with hammer
2	hammer on paper with hammer	lift phone to mouth
3	lift cup to mouth	hammer on paper with crayon
4	draw on paper with crayon	lift cup to ear

Materials. Four kinds of artifact were used: toy mobile phones, plastic handled cups, toy hammers, and crayons. As each condition comprised twenty trials in total, twenty objects of each kind were used, with 10 colored red and 10 colored blue. These objects were chosen as they each had a single specific action strongly associated with them: in pilot testing, more than 90% of children were able to spontaneously demonstrate the action associated with each of these artifacts. Following the method of Simpson and Riggs (2007), two strips of card were used (150 mm by 800mm), and eight artifacts were placed on each strip. A third strip of card concealed the artifacts so that children could not see the color of the item that would appear next.

Procedure. Each child completed an Associated and an Unassociated condition. Overall, four different combinations of action and artifact were used (shown in Table 1). Each child received one of these four combinations. So for example, in the Associated condition children were told to lift blue phones to their ear (go trials), but to make no response to red phones (no-go trials); and in the Unassociated condition, they were told to make a drawing action with blue hammers (go trials), but to make no response to red hammers (no-go trials). The combinations ensured that different artifacts and actions were used in the two conditions presented to a child. This was done to reduce the likelihood of carry-over effects between the two conditions. The order of administration of the conditions was also counterbalanced.

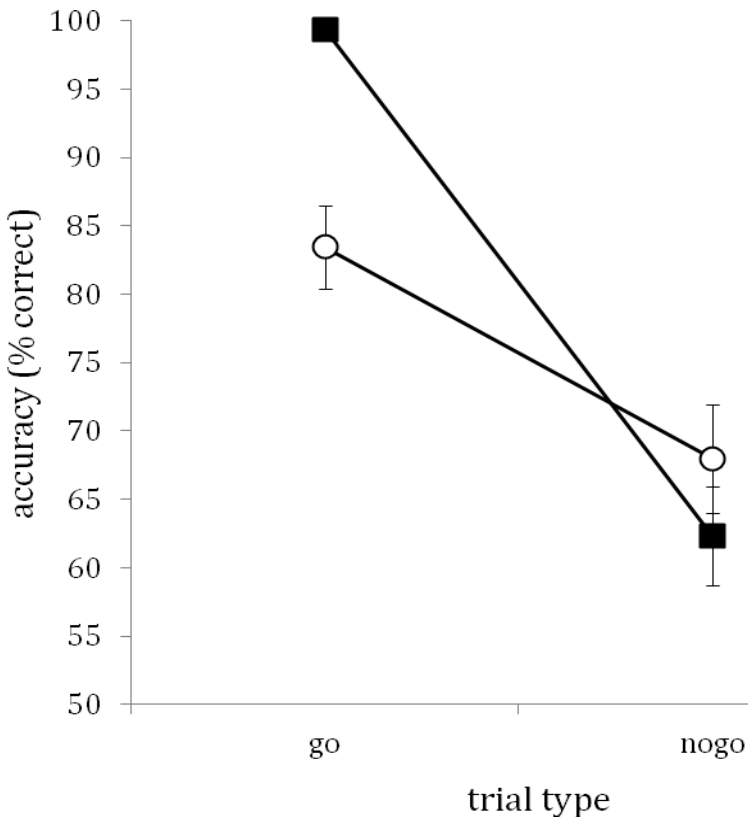
At the start of each condition, children received four practice trials with feedback (in a fixed order: go, no-go, go, no-go). Then, for the test trials, children were given a further reminder of the rules, after which eight objects were placed on the table, concealed by a strip of card. Objects were revealed one at a time, and children were given approximately two seconds to respond. If a child did not respond in that time, the response was recorded as 'no-go,' and the experimenter revealed the next object. After the first eight trials, the next eight objects were placed on the table, covered by the card. These objects were again revealed one at a time. Each child completed one Associated condition and one Unassociated condition. Within each condition, the 16 test trials were presented in a pseudorandom order, with eight go trials and eight no-go trials. No feedback was given.

Results

Mean accuracy is shown in Figure 1. Go accuracy was near ceiling in the Associated condition (almost 100%) but lower in the Unassociated condition (83%). No-go accuracy was low in both conditions (around 65%). Preliminary analyses found no significant order effect for completing the Associated or Unassociated condition first ($p = .20$), and no difference in performance according to the type of artifact used ($p = .11$). Data were analysed using a repeated-measures ANOVA, with Trial type (Go, No-go) and Artifact-action relation (Associated, Unassociated) as factors. There were significant main effects for Trial type,

$F(1,76)=51.45$, $p<.001$, $\eta^2=.404$, and Artifact-action relation, $F(1,76)=8.05$, $p=.006$, $\eta^2=.096$, as well as a significant interaction, $F(1,76)=13.83$, $p<.001$, $\eta^2=.150$.

Figure 1. Accuracy on go and no-go trials for the Associated condition (black squares) and the Unassociated (white circles) condition. Error bars show the standard error of the mean.



A planned comparison looking only at no-go accuracy found no quantitative difference between the Associated and Unassociated conditions, $p=.140$. However, an analysis of the type of error made on no-go trials indicated a qualitative difference: In the Unassociated condition (e.g., hammering with a crayon) children erred by making both associated responses (drawing, on 10% of no-go trials) *and* unassociated responses (hammering, on 21% of no-go trials). In contrast, in the Associated condition (e.g., drawing with a crayon) children only erred by making the associated go response (drawing on 38% of no-go trials). Nevertheless, while children made associated responses in the Unassociated condition, they did so significantly less often than in the Associated condition ($t(79)=8.39$, $p<.001$, 95% CI 21 to 34%), in which they were told to make these responses.

There was significantly poorer go accuracy in the Unassociated condition than in the Associated condition, $t(79)=5.248$, $p<.001$, 95% CI 10 to 22%. This poor go accuracy was caused by children making the associated response (e.g., drawing with the crayon when they should have been hammering with it), rather than by them failing to respond at all. Thus, overall, children made associated errors on both go and no-go trials of the Unassociated condition, but never made unassociated errors on the Associated condition.

Discussion

The present study sought to investigate whether the associations children learn between artifacts and actions affect prepotency. An Associated condition (in which there was a learned association between artifacts and actions) was compared to an Unassociated condition (where artifacts and actions were unrelated). Behavior on these conditions differed, for both go and no-go trials. For go trials, in the Unassociated condition (e.g., when asked to make a hammering action with a crayon), children erred by making the response associated with that artifact (e.g., drawing with the crayon). In the Associated condition, children never produced any of the unassociated actions on go trials (e.g., they never hammered with a crayon). For no-go trials, conditions did not differ significantly in overall accuracy, as children made comparable *numbers* of no-go errors in the Associated and Unassociated conditions. Despite this, the conditions again differed in the *types* of errors made. Children in the Unassociated condition made both associated and unassociated errors (e.g., both drawing and hammering with a crayon); whereas in the Associated condition they only made associated errors (only drawing with the crayon).

Crucially however, despite these differences between the Associated and Unassociated conditions, children did make *some* unassociated errors on no-go trials in the Unassociated condition. So, for example, when told to hammer with a crayon on go trials, children did sometimes err by hammering on no-go trials. This finding suggests that actions made on artifacts can be prepotent *irrespective* of whether that action is associated with that artifact (e.g., hammering with a crayon can be prepotent). In this respect, the present Artifact Go/no-go data differ from previous results obtained with the Box-search task (Simpson & Riggs, 2007). In the box-search study, children made no unassociated (hoop-over) errors, consistent with the idea that unassociated actions are not prepotent in that task. One explanation for this between-task difference is that children were less impulsive when making the specific unassociated action used in the Box-search task (placing a hoop over boxes – Beck et al., 2011). Children had difficulty with all four unassociated actions used in the current study – which suggests that many unassociated actions can be prepotent. However, data from the Box-search task suggest that not *all* unassociated actions produce poor performance. Further research is needed to determine whether other unassociated actions can produce good performance on Go/no-go tasks. The question of what makes the hoop-over action different from the four used here also needs to be explored.

It is informative to consider the different kinds of error that children made in the Associated and Unassociated condition of the Artifact Go/no-go task. Young children sometimes erred by making associated actions in the Unassociated condition (on both go and no-go trials), but they never made unassociated actions in the Associated condition. It is unsurprising that children did not make a ‘random’ action – such as hammering with a crayon – unless they had previously been told to do so. What is important is that they *did* sometimes draw with crayons despite been asked to do something else. We suggest that it was only telling children to make the unassociated action on go trials that made it prepotent, and thus hard to inhibit, on no-go trials. In contrast, associated actions were prepotent irrespective of what children were asked to do. Thus our data suggest that young children have learned associations between specific artifacts and specific actions, and that this knowledge causes them to sometimes make associated actions in the Unassociated condition, even though these learned associations are not necessary to make the action prepotent. Any action can be prepotent in the Artifact Go/no-go task, as long as children are asked to make that action on go trials. To put it another way, the current data strongly suggest that prepotency can be derived both from previous experience, and from short-term, task-specific associations.

If both associated and unassociated actions can be prepotent in the Artifact Go/no-go task, the next question is whether they are equally prepotent, or whether one is more prepotent than the other. Is there evidence that associated actions are activated more strongly than unassociated ones? Data from the Unassociated condition can speak to this question. In this condition, children made around twice as many unassociated errors (21%) as associated errors (10%) on no-go trials. This suggests that unassociated actions are *more* prepotent than associated ones in this condition, and that specifying the response to be made at the start of a task is sufficient to make that response prepotent. However, in the Associated condition, children never made any unassociated actions, suggesting that these unassociated actions were not prepotent at all in this condition. Our findings extend and support previous research (e.g., Hanauer & Brooks, 2005;

Simpson & Riggs, 2011) suggesting that children's short-term goals or intentions (based on what they were asked to do in the task) strongly influence prepotency. The present findings add further weight to the notion that task demands can modulate the prepotency of an action.

In the Introduction we noted that much everyday behavior is made on artifacts. What do the current data tell us about young children's capacity to control this behavior? As Simpson and Riggs (2007) suggest, if children's intentions strongly influence prepotency then it is likely that, for the most part, only the artifact-actions children intend to make will be prepotent. If this is the case then inappropriate actions (i.e., those actions that conflict with current intentions) are unlikely to be prepotent and children's action control should be good. However, children may have problems preventing the over-extension of intended actions. So, for example, children may intend to cut a piece of paper with scissors, but move on to cutting a nearby book, and then to their own hair. This is essentially what happens in the go/no-go task: children's intended action spreads from go trials (where it is appropriate) to no-go trials (where it is not).

The current findings differ from the Box-search data (Simpson & Riggs, 2007) by demonstrating that it may be just as easy for unassociated actions (e.g., hammering with scissors) to get out of control as associated ones (e.g., cutting with scissors). Our data also speak to a further topic of long-standing interest to developmental psychologists (e.g., Jarrold, Carruthers, Smith & Boucher, 1994): what cognitive abilities allow children to engage in pretend play (e.g., pretending a hair-brush is a microphone)? The problem, in this context, is how do children with weak inhibitory control avoid the action associated with an artifact (e.g., putting a brush to your hair), when making an unassociated play action (e.g., putting a brush to your mouth)? As in our Unassociated condition, children's *intention* to make the unassociated play action may be sufficient to make it more prepotent than the associated action.

Research over the past two decades has established that inhibitory control plays a central role in the development of many important cognitive skills. Despite this, we still know little about the factors that determine when inhibition is needed. Careful experimental design will be required to disentangle these factors, and the present study offers one way of addressing this important question. It emphasizes that prepotency is not a simple phenomenon. Rather, it can be created by multiple sources, exerting influence on their own as well as in combination.

References

Barrett, T. M., Davis E. F., & Needham, A. (2007). Learning about tools in infancy. *Developmental Psychology*, *43*, 352-368.

Beck, S.R., Carroll, D.J., Brunsdon, V.E.A., & Gryg, C.K. (2011). Supporting children's counterfactual thinking with alternative modes of responding. *Journal of Experimental Child Psychology*, *108*, 190-202.

Hanauer, J.B., & Brooks, P. (2005). Contributions of response set and semantic relatedness to cross-modal Stroop-like picture-word interference in children and adults. *Journal of Experimental Child Psychology, 90* (1), 21-47.

Jarrold, C., Carruthers, P., Smith, P.K., & Boucher, J. (1994). Pretend play: is it metarepresentational? *Mind and Language*, *9*, 445-468.

Simpson, A., & Riggs, K.J. (2007). Under What Conditions Do Young Children Have Difficulty Inhibiting Manual Actions? *Developmental Psychology*, *43*, 417-428.

Simpson, A., & Riggs, K.J. (2011). Under what conditions do children have difficulty in inhibiting imitation? Evidence for the importance of planning specific responses. *Journal of Experimental Child Psychology, 109* (4), 512-524.

Simpson, A., Riggs, K.J, Beck, S.R., Gorniak, S.L., Wu, Y., Abbott, D., & Diamond, A. (2012). Refining the understanding of inhibitory processes: how response prepotency is created and overcome. *Developmental Science*, *15*, 62-73.