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**Where does prepotency come from on developmental tests of inhibitory control?**


## Abstract

Understanding the processes that make responses prepotent is central to understanding the role of inhibitory control in cognitive development. The question of what makes responses prepotent was investigated using the two most widely studied measures of preschoolers' inhibitory control. Across two experiments, 80 children were tested either on a series of Stimulus-Response Compatibility (SRC) tasks, or on a series of Go/No-go tasks. Results indicated that high levels of prepotency on SRC tasks (such as the Day/Night task) only occur under specific conditions: making a verbal response can be highly prepotent if the stimulus and response are associated with each other (e.g., saying "cup" to a cup); but is less prepotent when they are unassociated (e.g., saying "cup" to a doorstop). Action responses (e.g., lifting a cup to your mouth) show little prepotency, irrespective of whether the stimulus and response are associated. In contrast, with Go/No-go tasks, a much wider variety of behaviors are highly prepotent, regardless of whether the stimulus and response are associated. These data suggest that prepotency arises in very different ways depending on the type of task used. While both Go/No-go tasks and SRC tasks can make inhibitory demands, they do so for fundamentally different reasons.


Keywords: Inhibitory Control; Executive Function, Prepotency, Preschoolers.

Word count: 6,140

## Introduction

Inhibitory control is the ability to suppress cognitions and behaviors that are incompatible with current goals. Inhibitory control undergoes protracted development from infancy through to adulthood, with particularly marked changes between 2 and 5 years (Garon, Smith & Bryson, 2014; Johansson, Marciszko & Brocki, 2016; Petersen, Hoyniak, McQuillian, Bates & Staples, 2016; Simpson & Riggs, 2005a; Wiebe, Sheffield & Espy, 2012). While research clearly suggests that inhibitory control improves with age, this is only one part of a more complex story. To understand the place of inhibitory control in development, it is also necessary to understand how inhibitory demands are created in the first place – in other words, to understand where prepotency comes from (Simpson et al., 2012). A prepotent response is a response that would be made in a given situation without active reflection – that is, in the absence of intentional top-down control. In most instances, making a prepotent response is goal-appropriate (such as eating a delicious piece of chocolate). However, sometimes pursuing a goal requires that prepotent responses are inhibited, so that other more goal-appropriate behavior can be made instead (such as not eating a piece of chocolate, in order to lose weight).

Understanding how prepotency is created is important for four reasons (Simpson et al., 2012). First, understanding this process is necessary in order to identify which tasks require inhibitory control: only tasks which contain inappropriate prepotent responses will be inhibitory (e.g., Simpson, Cooper, Gillmeister & Riggs, 2013). Second, understanding this process in the laboratory will help understand when and why preschoolers' weak inhibitory control is exposed outside it. Correlational evidence suggests that improvements in inhibitory control are associated with the development of many important skills (e.g., Apperly & Carroll, 2009; Beck, Carroll, Brunsdon & Gryg, 2011; Benson, Sabbagh, Carlson & Zelazo, 2013; Cragg & Gilmore, 2013; Riggs, Jolley & Simpson, 2013; van Mourik, Oosterlaan & Sergeant, 2005). Nevertheless, it is not clear why inhibitory control is associated with these skills. A crucial question is, 'Does the presence of inappropriate prepotent responses directly block the expression of these skills?'. To answer this question, we need to understand the conditions that create prepotent responses. Third, the pattern of prepotency may change during development. Behavior which is prepotent at one point in development may not be prepotent at another. And finally, understanding prepotency can help us identify strategies to enable children to circumvent their inhibitory weakness (e.g., Simpson et al., 2012).

When seeking to understand how prepotency is created, we suggest that the best place to start is to consider measures of inhibitory control. A meta-analysis of developmental studies reported that around 70% of all studies into inhibitory control used two measures: Stimulus-Response Compatibility (SRC) tasks and Go/No-go tasks (Peterson et al., 2016). In the current article, we aimed to determine why responses are prepotent in these two measures.

Developmental inhibitory control tasks typically present children with a stimulus that evokes a prepotent response, which must then be inhibited. For example, on SRC tasks – a family of tasks that includes the Day/Night task and the Grass/Snow task – children are shown one of two stimuli, and asked to make one of two responses. On the Day/Night task, children must respond by saying "night" when they see a picture of a |sun|, and "day" when they see a picture of a |moon|. Crucially, the correct response on the task is to make a response that is different to the stimulus on that trial. Children must inhibit the tendency to make the response that is triggered by the stimulus (i.e., seeing |sun| triggers the incorrect response of saying “day”), in order to make the task-appropriate response instead (i.e., seeing |sun| and then saying “night”).

So where does this to-be-inhibited prepotency come from? One suggestion has been that prepotency on these tasks arises from a combination of two factors: intention and stimulus-response association (Simpson & Riggs, 2007). Intention refers to children specifically intending to make one or more particular responses on the task – typically because the task instructions explicitly direct them to do so. For example, on the Day/Night task, children are instructed to say either “day” or “night”. Since children therefore intend to make these two responses on the task, these two responses become primed (i.e., partially activated). Stimulus-response association refers to the stimuli and responses on a task being associated with each other, usually through previous experience. For example, a picture of a |moon| (a stimulus on the Day/Night task) is associated with the word “night” (a response on the task) because these two things have reliably co-occurred in children’s previous day-to-day experience.

A range of findings suggest that the role of intention in creating prepotency is straightforward (e.g., Simpson et al., 2012; Simpson, Carroll & Riggs, 2014). Simply put, if children intend to make a specific response, then that response can be prepotent; and if children do not intend to make that response, then that response cannot be prepotent. It is the intention to make a particular response that causes that response to be primed; this priming means that the response is held in a “hair-trigger” state, such that it requires much less additional activation to be output, relative to other responses the child could make. However, as we now outline, findings relating to the role of stimulus-response association are less straightforward, and its role in creating prepotency is less well understood.

Evidence from the Day/Night task is clearly consistent with the idea that prepotency arises because of stimulus-response associations (e.g., Simpson & Riggs, 2005b). On the standard Day/Night task, the word “day” (one of the two task responses) is associated with the picture of a |sun| (one of the two task stimuli); and the word “night” (the other task response) is associated with the picture of a |moon| (the other task stimulus). Inhibitory demands arise because, on every trial, the stimulus presented is associated with the task-inappropriate response. Seeing the picture of a |sun| triggers the associated response “day”, and seeing the picture of a |moon| triggers the associated response “night”. These associated responses must be inhibited, so that the task-appropriate responses can be made instead. On this standard version of the task, children perform poorly. However, when abstract pictures are used as stimuli – that is, pictures that are not associated with either the “day” or “night” response – children perform better (Gerstadt et al., 1994; Simpson & Riggs, 2005a). Thus, when the stimulus-response association is removed, the inhibitory demands of the task are greatly reduced. Since these abstract stimuli are unassociated with the task responses, the task-inappropriate response is not triggered more than the task-appropriate response, so little inhibitory control is required.

These findings support the idea that prepotency comes about, in part, because of stimulus-response association. Note that it is not merely the familiarity of the stimuli and responses that creates prepotency, but rather the specific association between them. Indeed, when familiar stimuli are combined with familiar responses that are not associated with each other (e.g., see |bird|, say “hat” / see |fish|, say “cup”), the Day/Night task has low inhibitory demands (Simpson et al., 2012). Familiarity is certainly necessary for prepotency, because only stimuli and response that are familiar can become associated. But familiarity alone is not sufficient; it is the strength of the association between these familiar stimuli and responses that determines prepotency.

However, recent findings suggest that the explanation for how prepotency arises may not be so straightforward (Simpson et al., 2014). The findings suggest, first, that stimulus-response association may not always influence prepotency, and second, that an additional factor needs to be considered: the type of response that children make on a task. We have noted on the Day/Night task that when children respond verbally, responses that are associated with stimuli (saying “day” to a picture of the |sun|) are more prepotent than those that are not associated with stimuli (saying “day” to an |abstract picture|). However, when children respond by making an action (e.g., making a drinking action in response to being shown a |cup|), a different pattern emerges.

The relevant evidence comes from a study using the Artefact Go/No-go task (Simpson et al., 2014). On the task, children are shown a series of objects. They are required to respond by making an action when presented with an object of one color (Go trials), and to make no response when presented with an object of another color (No-go trials). The role of stimulus-response association was investigated across two conditions. In the Associated condition, the Go-trial response was to make an action associated with the object (e.g., when presented with a |cup|, they had to lift the cup to their mouth). In the Unassociated condition, the Go-trial response was to make an action that was not associated with the object (e.g., when presented with a |cup|, they had to lift the cup to their ear). If prepotency arises because of an association between stimulus (the object) and response (the Go-trial action), then we would expect greater prepotency (and therefore more errors) in the Associated condition than in the Unassociated condition. However, children made as many errors with unassociated actions as they did with associated ones. Thus, these data suggest that, when making an action, responses which are not associated with the stimulus are just as prepotent as responses that are associated. It appears that when children respond by making an action, prepotency arises regardless of whether the responses on the task are associated with the stimulus or not.

So when considering where prepotency comes from, it may be that the importance of stimulus-response association differs depending on the type of response that children make (Simpson et al., 2014). Data are consistent with the idea that any action responsecan be highly prepotent (e.g., both lifting a cup to your mouth and lifting a cup to your ear can be highly prepotent); but verbal responses are more prepotent when they are associated with a stimulus than when they are not (e.g. saying "cup" to a |cup| is more prepotent than saying "cup" to a |phone|). However, such a conclusion may be premature, since one further factor must be considered: the type of task that children are tested on. In the studies reviewed above, the type of response children made (a verbal response versus an action response) is confounded with type of task used (an SRC task versus a Go/No-go task). Children made verbal responses on SRC tasks (Gerstadt et al., 1994; Simpson & Riggs, 2005a) and made action responses on Go/No-go tasks (Simpson & Riggs, 2007; Simpson et al., 2014). Thus, we cannot be certain whether the effect of stimulus-response association on prepotency arises as a function of the type of response children make, or as a function of the type of task that they are carrying out. So while previous data suggest that stimulus-response association plays some role in creating prepotency, precisely how it does so is unclear.

Prior research has indicated that prepotency arises through a combination of factors. One already identified factor is intention (i.e. intending to make particular responses on a task). There are three further factors that may, singly or in combination, play a role in determining prepotency: these are stimulus-response association, the type of response that children make, and the type of task used. The present study aimed to separate these three factors, to address the fundamental question of where prepotency comes from on developmental tests of inhibitory control. We ran two closely matched experiments – one using an SRC task, one using a Go/No-go task – each directly comparing the effect of stimulus-response association (associated versus unassociated) and type of response (verbal versus action). Together, these experiments allowed us to identify which factors give rise to prepotency on developmental measures of inhibitory control.

**Experiment 1**

Experiment 1 used a series of SRC tasks to investigate the effects of stimulus-response association and type of response on prepotency. Preschoolers' performance was compared on four closely matched versions of the SRC task, in which type of response (Verbal versus Action) and stimulus-response association (Associated versus Unassociated) were systematically varied. There were four SRC conditions: Action Associated, Verbal Associated, Action Unassociated, and Verbal Unassociated (see Table 1).

In the Action Associated SRC condition, on each trial, one of two familiar objects was shown, and children were asked to make the action associated with the other object. For example, when the stimuli objects were a cup and a phone, children were told to lift cups to their ear, and to put phones to their mouths. In the Verbal Associated SRC condition, children were shown the same two familiar objects, and were asked to say the name associated with the other object (e.g., say "cup" to |phone|, and say "phone" to |cup|). In the Action Unassociated SRC condition, children were shown two unfamiliar objects, and were asked to make a specific action with each. The actions were the same in the Associated and Unassociated conditions: it was the association between stimulus and response that differed between conditions. Thus, in the Action Unassociated SRC condition, children were asked to lift a |plumbing part| to their ear, and to put a |doorstop| to their mouth. Finally, in the Verbal Unassociated SRC condition, children were shown two unfamiliar objects and asked to make specific verbal responses (say "cup" to a |plumbing part|, and say "phone" to a |doorstop|).

## Method

### Participants

Forty preschool children (age range 3;0 - 4;4 years, mean age 3;7) attending a preschool in rural England took part in the study. All spoke English as their first language, and none had any behavioral or educational problems (based on teacher report). The group was predominantly white and of mixed social class. Ethical approval was granted by the University ethics committee. Informed consent was obtained from parents and the head of the nursery school.

## Design

A within-participants 2x2 design was used, with Type of response (Action, Verbal) and Stimulus-response association (Associated, Unassociated) as factors. The dependent variable was accuracy.

## Materials

Eight objects were used (see Figure 1). Four of the objects were familiar (toy mobile phone; plastic cup; toy hammer; crayon) and four were unfamiliar (plumbing part; doorstop; touch-light; hose part). Pilot data (n=20) were collected to check that preschool children knew the names and actions associated with the familiar objects, but did not know the names and actions associated with the unfamiliar objects. Children could produce 76% of the names and 83% of actions associated with the familiar objects. In contrast, they could produce just 5% of the names and 4% of actions associated with the unfamiliar objects.

## Procedure

Each child completed all four conditions (Action Associated, Verbal Associated, Action Unassociated, and Verbal Unassociated). Tasks were administered over two sessions not more than two weeks apart, with the two Associated conditions in one session, and the two Unassociated conditions in the other session. The order of presentation of the four conditions was counterbalanced.

All conditions shared the same basic procedure. For example, in the Verbal Associated SRC condition, the experimenter said “When I give you a |cup|, say ‘phone’, and when I give you a |phone|, say ‘cup’”. Children were asked to repeat the responses. Children were explicitly told not to name the objects, and were reminded of the rules before testing began. For each condition, there were four practice trials, with feedback. There then followed 16 test trials (8 trials with each type of object), presented in a pseudo-random order and without feedback. The objects were arranged in a line, and the experimenter moved down the line, pointing to each object in turn for about two seconds. The experimenter encouraged the child to make a response. Meanwhile, a confederate recorded these responses. If the child made more than one response, accuracy was based on the first response.

## Results and Discussion

Accuracy on the four conditions is shown in Figure 2. Accuracy was poor on the Verbal Associated SRC condition (55%), but was better on the other three conditions (around 80%). There were no significant order effects, nor any effects involving object type.

Data were analysed in a repeated-measures ANOVA, with Type of response (Action, Verbal) and Stimulus-response association (Associated, Unassociated) as factors. There were significant main effects for both Type of response, $F(1,39)=11.2$, $p=.002$, $\eta^2=.223$, and Stimulus-response association, $F(1,39)=34.2$, $p<.001$, $\eta^2=.467$. There was also a significant interaction between Type of response and Stimulus-response association, $F(1,39)=5.05$, $p=.030$, $\eta^2=.115$. Stimulus-response association affected accuracy with verbal responses: accuracy was poorer in the Verbal Associated SRC condition than in the Verbal Unassociated SRC condition, $t(39)=3.28$, $p=.002$, 95% CI 8.28 to 34.8%. However, there was no effect of Stimulus-response association on accuracy with action responses: accuracy in the Action Associated SRC condition and the Action Unassociated SRC condition did not differ ($p=.284$).

These data suggest that stimulus-response association and type of response interact when preschoolers perform SRC tasks. Children found it harder to inhibit associated verbal responses than unassociated ones (consistent with previous findings – e.g., Gerstadt et al., 1994); however, children had little difficulty in inhibiting actions, whether they were associated or unassociated (a new finding in this experiment). Of the four combinations of responding reported here (Action Associated, Verbal Associated, Action Unassociated, and Verbal Unassociated), verbal responses associated with the stimulus – saying "cup" to a |cup| – were the most prepotent in SRC tasks. In other words, highly prepotent responses only arise on SRC tasks under a very specific set of circumstances.

## Experiment 2

Experiment 2 used a series of Go/No-go tasks (rather than SRC tasks) to investigate the effects of stimulus-response association and type of response on prepotency. Children's performance was compared on four closely matched versions of the Artefact Go/No-go task, in which type of response (Verbal versus Action) and stimulus-response association (Associated versus Unassociated) were systematically varied (as in Experiment 1). There were four Go/No-go conditions: Action Associated, Verbal Associated, Action Unassociated, and Verbal Unassociated (see Table 1). The eight objects used in Experiment 2 were identical to those used in Experiment 1.

In the Action Associated Go/No-go condition, children were shown a series of familiar objects of a single type, but in two different colors (red or blue). For example, children were presented with a series of cups, one at a time, and were asked to put the red cups to their mouth (Go trials) and to make no response with blue cups (No-go trials). Thus, in the Action Associated Go/No-go condition, children were asked to produce the action associated with the object on Go trials, and to make no response on No-go trials. In the Action Unassociated Go/No-go condition, children were shown a series of unfamiliar objects of a single type (e.g., a plumbing part), in either red or blue. The Go responses were the same as those used in the Action Associated condition (e.g., lifting the object to the mouth), but in the Action Unassociated condition these actions were not associated with the objects with which they were made (e.g., lifting a |plumbing part| to the mouth).

The two Verbal conditions were constructed in a similar way. Children were asked to make a verbal response on Go trials, and to make no response on No-go trials. In the Verbal Associated Go/No-go condition, the Go response was associated with the object (say "cup" to a |cup|); and in the Verbal Unassociated Go/No-go condition, the Go response was not associated with the object (say "cup" to a |plumbing part|).

**Method**

Participants

Forty preschool children (age range 3;0 – 4;4 years, mean age 3;9) from nurseries in rural England took part in the study. Otherwise the participants' demographics were similar to those of Experiment 1.

Design and Materials

A within-participants 2x2x2 design was used, with Trial type (Go, No-go), Type of response (Action, Verbal) and Stimulus-response association (Associated, Unassociated) as factors. The dependent variable was accuracy. The materials were identical to Experiment 1, except that for each type of object, there were 10 red items and 10 blue items (objects were either the appropriate color, or were spray-painted).

Procedure

Each child completed all four conditions (Action Associated, Verbal Associated, Action Unassociated, and Verbal Unassociated). Tasks were administered over two sessions not more than two weeks apart, with the two Associated conditions in one session, and the two Unassociated conditions in the other session. The order of presentation of the four conditions was counterbalanced. All conditions shared the same trial structure. For example, in the Verbal Associated Go/No-go condition, children were presented with a series of cups on a table: half the cups were red, and half were blue. The experimenter said, "When I point to a |red cup|, say 'cup', and when I point to a |blue cup|, say nothing". For each condition, there were four practice trials, with feedback. There followed 20 test trials, presented in a pseudo-random order (10 Go trials and 10 No-go trials). Feedback was not given on test trials. As in the SRC tasks, a confederate recorded children's responses. A response was recorded as 'go' once the child had picked up the object, and as 'no-go' if the child did not pick it up within about two seconds (at which time the experimenter moved on to the next object).

**Results and Discussion**

Accuracy on Go trials was high in all four conditions (from 95% to 98%; see Figure 3). Accuracy on No-go trials was lower (from 73% to 79%). There were no significant effects that involved order or object type (i.e., which one of the eight objects was used).

Data were analysed in a repeated-measures ANOVA, with Trial type (Go, No-go), Type of response (Action, Verbal) and Stimulus-response association (Associated, Unassociated) as factors. There was a significant main effect of Trial type, $F(1,39)=41.2$

$p<.001$, $\eta^2=.513$, but no other significant main effects or interactions. The effect of Trial type was due to better Go trial accuracy than No-go trial accuracy. This difference reflects the inhibitory demands of the No-go trials, as Go responses must be inhibited on No-go trials (Simpson & Riggs, 2007). No-go accuracy did not differ across conditions, regardless of whether the responses were verbal or actions, $F(1,39)=0.072$, $p=.789$, and regardless of whether the responses were associated with the stimuli or not, $F(1,39)=0.605$, $p=.441$. Overall, these findings are consistent with the idea that any response can be highly prepotent in a Go/No-go task.

These data suggest that neither stimulus-response association nor the type of response affect prepotency on preschool Go/No-go tasks. On No-go trials, children found it just as hard to inhibit unassociated responses as associated responses, irrespective of whether those responses were verbal or actions. It appears that intention alone is sufficient to determine prepotency in Go/No-go tasks: intending to make the response on Go trials also makes that response prepotent on No-go trials, irrespective of the nature of the Go response.

This observation has an important implication for the literature. Based on findings using a Go/No-go task, Simpson et al. (2014) concluded that action responses are different from verbal responses. Specifically, they suggested that the prepotency of verbal responses is affected by stimulus-response association (saying “cup” to a |cup| is more prepotent than saying “cup” to a |plumbing part|); but that the prepotency of action responses is not affected by stimulus-response association (any action made with an object can be prepotent). However, the data from Experiment 2 suggest that neither the prepotency of names nor the prepotency of actions is affected by stimulus-response association, when performing a Go/No-go task.

## General Discussion

Taken together, the results of these two experiments show that prepotency arises for different reasons on SRC tasks and Go/No-go tasks. On SRC tasks, high levels of prepotency arise only under a narrowly defined set of circumstances (Experiment 1). Performance was poor in the Verbal Associated condition – indicating the presence of a highly prepotent response – but good in the other three conditions (Action Associated, Verbal Unassociated, Action Unassociated). Thus, on SRC tasks high levels of prepotency only arise when children make verbal responses – and even then, only when the stimuli and responses used in the task were associated with each other (e.g., saying "cup" to a |cup|). Prepotency was much lower when a verbal response was not associated with the stimulus (e.g., saying "cup" to a |doorstop|). It was also low for action responses, regardless of whether those actions were associated with the task stimulus (lifting a |cup| to your mouth) or not (lifting a |doorstop| to your mouth). The picture for Go/no-go tasks, in contrast, was simpler (Experiment 2). Children performed poorly on No-Go trials in all four conditions (Action Associated, Verbal Associated, Action Unassociated, and Verbal Unassociated). Thus, these data are consistent with the proposal that a range of responses can be highly prepotent on Go/No-go tasks, and that prepotency is unaffected by stimulus-response association.

Previous research suggested that prepotency on developmental inhibitory control tasks depends on intention (e.g., Simpson et al., 2012, 2014). The present data confirm that intention has a central role in determining prepotency on both Go/No-go and SRC tasks. However, the present data go well beyond this, and allow us to offer a more detailed account of how prepotency arises on the measures of inhibitory control used most with young children (Peterson et al., 2016). Although these two types of task measure the same construct, they are importantly different in the source of their prepotency. We now consider how prepotency is created on SRC tasks and Go/No-go tasks in turn.

The origin of prepotency in SRC tasks

In SRC tasks, the intention to respond plays a causal role in determining prepotency (e.g., Simpson et al., 2012). However, the effect of intention is mediated by stimulus-response association. Prepotency is high only when task stimuli and responses are associated. Thus, when the task-inappropriate response is more strongly associated with the stimulus than the task-appropriate response is, the inappropriate response is triggered more, and inhibitory demands will be high. It is this relative difference in the association of these responses with the stimulus that creates prepotency on SRC tasks. For example, consider an SRC task with the rules 'see |cup|, say "phone"' and 'see |phone|, say "cup"'. When the stimulus |cup| is presented, the task-inappropriate response "cup" is more strongly associated with that stimulus than is the task-appropriate response "phone". The stimulus |cup| triggers the response "cup" more than it triggers the response "phone", because in children's previous everyday experience, a picture of a |cup| is associated with the word "cup" more than it is associated with the word "phone". SRC tasks only have high inhibitory demands when there is a significant difference between the relative association of the two responses with the stimulus. Without this difference – for example, when abstract pictures are used as stimuli – the task-inappropriate response is not triggered more than the task-appropriate response. In this scenario, the task's inhibitory demands are low, because there is little need to inhibit an inappropriate response before making the appropriate response.

Experiment 1 showed that stimulus-response association affects prepotency more when children make verbal responses than when they make action responses. Why is it that making associated verbal responses (e.g., saying "cup" to |cup|) is more prepotent than making associated action responses (e.g., lifting a |cup| to your mouth)? We suggest that the most parsimonious explanation is that the strength of the association between a stimulus object and its name is greater than the strength of association between a stimulus object and its action. The preschoolers in the studies reported here knew both the names and the actions associated with the familiar objects used in this study (as confirmed in our pilot testing). So it is clearly not the case that children were aware of the objects' names, but unaware of the actions made with them. However, familiarity alone is not sufficient to give rise to prepotency. Rather, prepotency emerges when a specific stimulus is repeatedly and reliably associated with a specific response . In order for a response to become prepotent, it is necessary that the association between stimulus and response is a strong one (e.g., Isoda & Hikosaka, 2011; Norman & Shallice, 1986; Shiffrin & Schneider, 1977). Thus, the difference we observed between verbal responses and action responses may lie in the strength of their association to specific stimuli.

To develop this idea further: when verbally labeling objects, names are generally used in a highly consistent way. The object |cup| is consistently labeled with the word "cup", and rarely (if ever) with other labels. This one-to-one correspondence is essential for effective communication between speakers, and it makes the association between an object and its name a strong one. In contrast to names, the actions made with objects are typically much more variable, and generally involve no communicative intent. For example, we commonly act on cups in lots of ways: we pour drinks into them, we hand them to other people, we carry them about, we invert them in a dishwasher or clean them by hand, and we stack them on shelves or hang them on hooks. While lifting a cup to your mouth is certainly something we do with a cup (when using it to fulfill its canonical function), this action is not uniquely associated with this object. It is just one of several actions commonly made with it. Consequently, on SRC tasks, low one-to-one correspondence between this stimulus and response may limit its prepotency. The associated actions used in this study were more closely associated with the objects than were the unassociated actions. Nevertheless, the strength of these associations may still have been relatively weak: too weak to give rise to measurable prepotency in a SRC task.

Our observation that the prepotency of actions made with objects is low on SRC tasks is true for the actions studied in Experiment 1, but does not generalize to all kinds of action. The account proposed in the previous paragraph explains why actions made with objects are less prepotent than naming. There is, however, clear evidence to suggest that some kinds of action can be highly prepotent when preschoolers make them in SRC tasks. For example, on the Grass/Snow task, declarative pointing is prepotent (e.g., hear “grass”, point to |white card| / hear “snow”, point to |green card|: Carroll et al., 2012; Simpson & Riggs, 2009) and in the Hand game, manual imitation is prepotent (see |finger gesture|, make |fist gesture| / see |fist gesture|, make |finger gesture|: Simpson & Riggs, 2011; Simpson, Cooper, Gillmeister & Riggs, 2013).

That both declarative pointing and manual imitation are prepotent is consistent with our proposal that stimulus-response association drives prepotency in SRC tasks. Declarative pointing involves communicative intent, just like naming, and so requires a high degree of one-to-one correspondence (e.g., consistently pointing to named objects). Likewise, theories of sensorimotor development (e.g., Piaget, 1952; Heyes & Ray, 2000) suggest that imitation becomes prepotent because of the high degree of one-to-one correspondence between perceptual representations of our own actions (the stimulus) and the motor representations used to make them (the response). Thus, when considering where prepotency comes from on developmental tasks, the type of action made is less important than the strength of the association between the task's stimuli and responses.

### The origin of prepotency in Go/No-go tasks

Prepotency arises on Go/No-go tasks in a much simpler way. Experiment 2 showed that responding was prepotent in all four conditions (Action Associated, Verbal Associated, Action Unassociated, Verbal Unassociated). In particular, it is notable that – as observed in the two Unassociated conditions – prepotency is relatively high even when the stimuli and responses are unassociated. This finding is consistent with previous research suggesting that a wide range of actions can be prepotent on Go/No-go tasks. In particular, evidence from computer-based Go/No-go tasks shows that the response of pressing a button can be prepotent when made in response to a wide range of unassociated stimuli, including shapes (Espy, 1997), animals (Simpson & Riggs, 2006) and lights (Flynn, O'Malley & Wood, 2004; Perner, Lang & Kloo, 2002). In fact, the only behavior that we are aware of in the published literature that appears not to be prepotent on Go/No-go tasks is placing a hoop over a box (a variant of the box search task: Simpson & Riggs, 2007). It has been suggested that this behavior may have low inhibitory demands because children are slow to produce this response (Simpson et al., 2014), and delaying responding reduces inhibitory demands (Simpson et al., 2012).

Taken together, these results suggest that the intention to respond on Go/No-go tasks is sufficient on its own to create relatively high levels of prepotency, irrespective of any other factor. The intention to make a response on Go trials causes that response to be primed. This priming remains active for the duration of the task, including on No-go trials. However, although the priming is helpful on Go trials, as it means that the correct response can be made swiftly, the priming is not helpful on No-go trials, as it makes it more likely that a task-inappropriate response will be made. Poorer No-go performance than Go performance reflects the facilitating effect that response priming has on Go trials, and the impairing effect it has on No-go trials.

The data in Experiment 2 provide evidence that any response can be prepotent in a Go/No-go task. However, it may still be the case that stimulus-response associations can enhance prepotency in Go/No-go tasks under certain circumstances. In the tasks used in Experiment 2, Go trials and No-go trials were distinguished by an object's color (e.g., see |red cup|, lift to mouth / see |blue cup|, do nothing). The objects' identity – the fact that they were cups – was irrelevant, and could be ignored. That being the case, it seems unlikely that information associated with them being cups was activated at all. Without the activation of such category-relevant information in these Go/No-go tasks, it is unlikely that stimulus-response association would have any effect on prepotency.

Nevertheless, we suggest that it is quite possible that an effect of stimulus-response association could be observed on some variants of the Go/No-go paradigm: specifically, on those variants with rules requiring children to identify the objects presented in the task. For example, consider a Go/No-go task with the rules “see |phone|, say ‘cup’ / see |cup|, say nothing”. In order to apply the rules on this task, children would need to identify stimuli as either |cups| or |phones|. It is possible that more inhibitory control would be required on No-go trials where the stimulus and the Go response are associated (e.g., stopping a Go response of saying “cup” when |a cup| is presented) than on No-go trials where they are not (e.g., stopping a Go response of saying “cup” when |a phone| is presented). This intriguing possibility should be explored in future research.

When do preschoolers use inhibitory control in everyday life?

Our findings have implications for preschoolers’ behavior outside the laboratory. First, our Go/No-go data suggest that when the alternative is to do nothing, almost any behavior can be highly prepotent. In contrast, our SRC data suggest that high levels of prepotency are far more restricted when selecting between alternative responses. Thus, in everyday life, preschoolers may find doing nothing particularly difficult – since it effectively requires them to successfully inhibit any behaviour that occurs to them (as in a Go/No-go task). Conversely, they may find it much easier to inhibit one behaviour in order to perform another (as in SRC tasks). Thus, these data suggest that if you wish to stop preschoolers engaging in a specific behavior, it may be more effective to get them to do something else, rather than insist that they do nothing.

Second, the research presented here investigated preschoolers’ verbal and manual behaviour with objects. The findings suggests that familiar verbal behavior with objects (i.e., naming) is more prepotent than familiar manual behavior with objects (i.e., making the actions associated with their use). This suggests that outside the laboratory, children may find it easier to be flexible when acting on objects than when naming them. This proposal offers a potential answer for a long-standing question in developmental psychology (e.g., Jarrold, Carruthers, Smith & Boucher, 1994): How can it be that young children, with their weak inhibitory control, manage to successfully engage in pretend play (e.g., pretending that a hair brush is a microphone)? The present data suggest the possibility that little inhibitory control is required to replace a familiar action on an object (brushing your hair) with an unfamiliar action on the same object (putting a brush to your mouth). That being the case, pretend play may in fact require very low levels of inhibitory control.

## Conclusion

SRC and Go/No-go tasks are the most widely used measure of inhibitory control in preschool children (used in about 70% of studies – Peterson et al, 2016). Despite such widespread use, this is the first study to systematically examine how prepotency is created in these two types of task: it is also the first study to explain why these measures of inhibitory control are actually measures of inhibitory control at all. The present data suggest that – beyond a common role for intention – prepotency is created in fundamentally different ways in SRC tasks and Go/No-go tasks. Future research should investigate whether this difference is observed across the whole of development, and also to what extent it interacts with other task characteristics (such as how responding is cued). Given the widely acknowledged importance of inhibitory control during the preschool and early school years, gaining a fuller understanding of such a fundamental question is likely to have important broader implications for cognitive development in the preschool years, and beyond.

**References**

Apperly, I., & Carroll, D.J. (2009). How do symbols affect 3-4-year olds'-executive function? Evidence from a reverse-contingency task. Developmental Science, 12, 1070-1082.

Beck, S.R., Carroll, D.J., Brunsdon, V, & Gryg, C. (2011). Supporting children's counterfactual thinking with alternative modes of responding. Journal of Experimental Child Psychology, 108 (1), 190-202.

Benson, J.E., Sabbagh, M.A., Carlson, S.M., & Zelazo, P.D. (2013). Individual Differences in Executive Functioning Predict Preschoolers' Improvement From Theory-of-Mind Training. Developmental Psychology, 49, 1615-1627.

Carroll, D.J., Riggs, K.J., Apperly, I.A., Graham, K., & Geoghegan, C. (2012). How do alternative ways of responding influence 3- and 4-year-olds' performance on tests of executive function and theory of mind? Journal of Experimental Child Psychology, 112, 312-325.

Cragg, L., & Gillmore, C. (2013). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. Trends in Neuroscience and Education, 3, 63-68.

Espy, K.A. (1997). The shape school: assessing executive function in preschool children. Developmental Neuropsychology, 13, 495-499.

Flynn, E., O'Malley, C., & Wood, D. (2004). A longitudinal, microgenetic study of the emergence of false belief understanding and inhibition skills. Developmental Science, 7, 103–115.

Garon, N., Smith, I.M., & Bryson, S.E. (2014). A novel executive function battery for preschoolers: sensitivity to age differences. Child Neuropsychology, 20, 713-736.

Gerstadt, C.L., Hong, Y.J., & Diamond, A. (1994). The relationship between cognition and action: performance of children 3.5 to 7 years old on a Stroop-like day-night test. Cognition, 53, 129-153.

Heyes, C., & Ray, E. (2000). What is the significance of imitation in animals? Advances in the Study of Behavior, 29, 215–245.

Isoda, M., & Hikosaka, O. (2011). Cortico-basal ganglia mechanisms for overcoming innate, habitual and motivational behaviours. European Journal of Neuroscience, 33, 2058-2069.

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

Johansson, M., Marciszko, C., & Brocki, K. (2016). Individual Differences in Early Executive Functions: A Longitudinal Study from 12 to 36 Months. Infant and Child Development, 25, 533-549.

Norman, D.A., & Shallice, T. (1986). Attention to action: willed and automatic control of behaviour. In R.J. Davidson, G.E. Schwarts & D. Shapario (Eds.), Conscious self regulation. Advances in research and theory. Vol. 4 (pp. 1-18). New York. Plenum Press.

Perner, J., Lang, B., & Kloo, D. (2002). Theory of mind and self-control: More than a common problem of inhibition. Child Development, 73, 752–767.

Petersen, I.T., Hoyniak, C.P., McQuillian, M.E., Bates, J.E., & Staples, A.D. (2016). Measuring the development of inhibitory control: The challenge of heterotypic continuity. Developmental Review, 40, 25-71.

Piaget, J. (1952). The origins of intelligence. New York: International University Press.

Riggs, K.J., Jolley, R.P., & Simpson, A. (2013). The role of inhibitory control in the development of human figure drawing in young children. Journal of Experimental Child Psychology, 114, 537-542.

Shiffrin, R., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 84, 127–190.

Simpson, A., Carroll, D.J., & Riggs, K.J. (2014). Prepotency in action: Does children's knowledge of an artefact affect their ability to inhibit acting upon it? Journal of Experimental Child Psychology, 118, 127-133.

Simpson, A., Cooper, N.R., Gillmeister, H., & Riggs, K.J. (2013). Seeing triggers acting, hearing does not trigger saying: Evidence from children’s weak inhibition. Cognition, 128, 103-112.

Simpson, A., & Riggs, K.J. (2005a). Inhibitory and working memory demands of the day-night task in children. British Journal of Developmental Psychology, 23, 471-486.

Simpson, A., & Riggs, K.J. (2005b). Factors responsible for performance on the day-night task: Response set or semantic relation? Developmental Science, 8, 360-371.

Simpson, A., & Riggs, K.J. (2006). Do young children experience inhibitory difficulty with a 'button-press' go/no-go task? Journal of Experimental Child Psychology, 94, 18-26.

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. (2009). What makes responses prepotent for young children? Insights from the grass-snow task. Infant and Child Development. Infant and Child Development, 18, 21-35.

Simpson, A., & Riggs, K.J. (2011). Under what conditions do children have difficulty inhibiting imitation? Evidence for the importance of planning specific responses. Journal of Experimental Child Psychology, 109, 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 control: How response prepotency is created and overcome. Developmental Science, 15, 62-73.

van Mourik, R., Oosterlaan, J., & Sergeant, J. (2005). The Stroop revisited: A meta-analysis of interference control in AD/HD. Journal of Child Psychology and Psychiatry, 46, 150-165.

Wiebe, S.A., Sheffield, T.D., & Espy, K.A. (2012). Separating the fish from the sharks: a longitudinal study of preschool response inhibition. Child Development, 83, 1245-1261.

**Figure 1.** The eight objects used in Experiments 1 and 2. The familiar objects were a phone, a cup, a hammer and a crayon. The unfamiliar objects were a doorstop, a touch-light, a hose part, and a plumbing part.

**Figure 2.** Accuracy on SRC tasks in Experiment 1 by Type of response and Stimulus-response association. Error bars show the standard error of the mean.

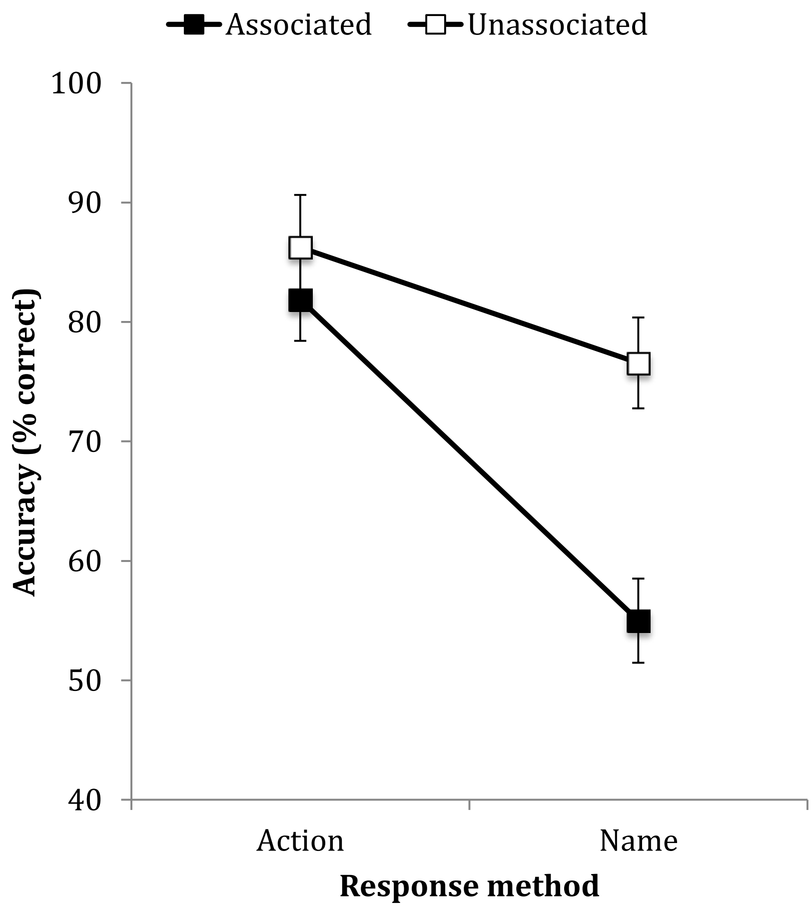

**Figure 3.** Accuracy on Go/No-go tasks in Experiment 2 by Type of response, Stimulus-response association and Trial type. Error bars show the standard error of the mean.

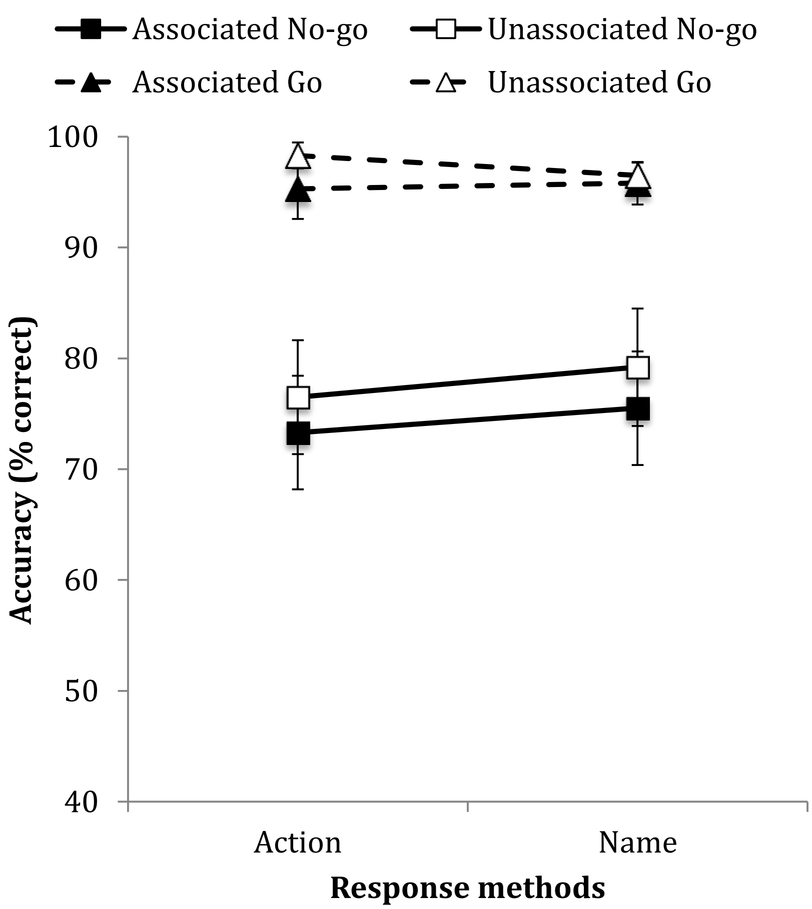

**Table 1.** Examples of the rules used in the SRC and Go/No-go tasks.

| | **Type of response** | |
|---|---|---|
| **Association** | **Action** | **Name** |
| | Experiment 1: SRC tasks | |
| Associated | See \|cup\|, put to ear | See \|cup\|, say "phone" |
| | See \|phone\|, put to mouth | See \|phone\|, say "cup" |
| Unassociated | See \|plumbing part\|, put to ear | See \|plumbing part\|, say "phone" |
| | See \|doorstop\|, put to mouth | See \|doorstop\|, say "cup" |
| | Experiment 2: Go/No-go tasks | |
| Associated | See \|red cup\|, put to mouth | See \|red cup\|, say "cup" |
| | See \|blue cup\|, make no response | See \|blue cup\|, make no response |
| Unassociated | See \|red doorstop\|, put to mouth | See \|red doorstop\|, say "cup" |
| | See \|blue doorstop\|, make no response | See \|blue doorstop\|, make no response |