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Brief Report

Working memory constraints on imitation and emulation

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A B S T R A C T

Does working memory (WM) constrain the amount and type of information children copy from a model? To answer this question, preschool-age children ($N = 165$) were trained and then tested on a touch-screen task that involved touching simultaneously presented pictures. Prior to responding, children saw a model generate two target responses: Order (touching all of the pictures on the screen in a target sequence three consecutive times) and Multi-Tap (consistently touching one of the pictures two times). Children's accuracy copying Order and Multi-Tap was assessed on two types of sequences: low WM load (2 pictures) and high WM load (3 pictures). Results showed that more children copied both Order and Multi-Tap on 2-picture sequences than on 3-picture sequences. Children who copied only one of the two target responses tended to copy only Order on 2-picture sequences but only Multi-Tap on 3-picture sequences. Instructions to either copy or ignore the Multi-Tap response did not affect this overall pattern of results. In sum, results are consistent with the hypothesis that WM constrains not just the amount but also the type of information children copy from models, potentially modulating whether children imitate or emulate in a given task.

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Introduction

Children are flexible social learners. In some instances, children imitate with exquisite fidelity, resulting in "overimitation." That is, they copy both causally relevant and causally irrelevant actions (Horner & Whiten, 2005; Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons, Young, & Keil, 2007). In other instances, children copy others' actions selectively, resulting in emulation. That is, they achieve a demonstrated goal by copying some actions while ignoring others (Nagell, Olguin, & Tomasello, 1993; Whiten, Custance, Gomez, Teixidor, & Bard, 1996) or achieve the demonstrated goal using idiosyncratic means (Gergely, Bekkering, & Kiraly, 2002; Meltzoff, 1988; Wood, 1989). But exactly why children imitate in some instances and emulate in others is a matter of great debate. Explanations fall into two broad camps that are domain specific: physical–causal (causal) and social–cultural (social). Causal theories emphasize that high-fidelity imitation, including overimitation, is a product of our species' long history with artifacts. Because the functions of many artifacts are opaque, it is proposed that we inhibit our own intuitions about the causal relevance of certain actions and imitate indiscriminately (Lyons, 2009; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). In contrast, social theories emphasize the fact that imitation is inherently social (Over & Carpenter, 2012; Uzgiris, 1981) and, importantly, occurs outside the artifact domain. Proponents of this view highlight the fact that imitation is influenced by a variety of factors, including the model's age (Zmyj, Aschersleben, Prinz, & Daum, 2012), social engagement (Nielsen & Blank, 2011), and whether the demonstrated actions are intentional or accidental (Zmyj, Buttelmann, Carpenter, & Daum, 2010), among many others (for a review, see Over & Carpenter, 2012).

These domain-specific theories have largely neglected domain-general cognitive processes that likely constrain both imitation and emulation. Working memory (WM), the ability to temporarily store and manipulate information (Baddeley, 1986, 2012), is a critical domain-general process that constrains the amount of information that children copy in a task (Bauer, 1992; Bauer & Hertsgaard, 1993; Bauer & Mandler, 1989; Bauer, Van Abbema, & de Haan, 1999; Harnick, 1978; Kemps, De Rammelaere, & Desmet, 2000; Simpson & Riggs, 2011). Yet, there is relatively little work on whether WM also constrains the *type* of information that children copy when they fail to imitate and, instead, emulate (e.g., Dickerson, Gerhardstein, Zack, & Barr, 2013; Simpson & Riggs, 2011). For instance, emulation might be a consequence of a task exceeding children's WM capacity. In this case, WM might predict what is most likely to be copied or ignored, potentially explaining some instances of imitation, overimitation, and emulation. We focused on WM, as opposed to other domain-general cognitive processes such as selective attention, for purely practical reasons. Although our current paradigm can be used to effectively manipulate WM load, it is less well-suited to assess attention.

Here, we tested WM constraints on imitation and emulation using a computerized imitation paradigm, the Cognitive Imitation Task (Fig. 1). This is a serial task that has been widely used to assess imitation learning in many different populations such as monkeys (Subiaul, Cantlon, Holloway, & Terrace, 2004), preschool-age children (Subiaul, Anderson, Brandt, & Elkins, 2012; Subiaul, Romansky, Cantlon, Klein, & Terrace, 2007; Subiaul, Vonk, & Rutherford, 2011), and individuals with autism (Subiaul, Lurie, et al., 2007).

The Cognitive Imitation Task is analogous to the Corsi and Knox tasks that have been widely employed to assess visual–spatial WM (Baddeley, 2012) in adults (Corsi, 1972; Kessels, van den Berg, Ruis, & Brands, 2008; Rossi-Arnaud, Pieroni, Spataro, & Baddeley, 2012) and in children (Kemps et al., 2000).[1] We used the Cognitive Imitation Task here because many studies on imitation (specifically overimitation) have employed object-based tasks such as puzzle/problem boxes where children must execute serial actions on objects to achieve a goal. Although these tasks may be more ecologically valid than the Cognitive Imitation Task, they cannot control for differences in affordances, familiarity, or top-down knowledge between tasks. And, importantly, the Cognitive Imitation Task allows the assessment of imitation learning within participants and across varying levels of difficulty.

[1] One important difference between the Cognitive Imitation Task and the Corsi and Knox tasks is that the Cognitive Imitation Task assesses visual skills independently of spatial skills, whereas most visual–spatial WM tasks confound the two.

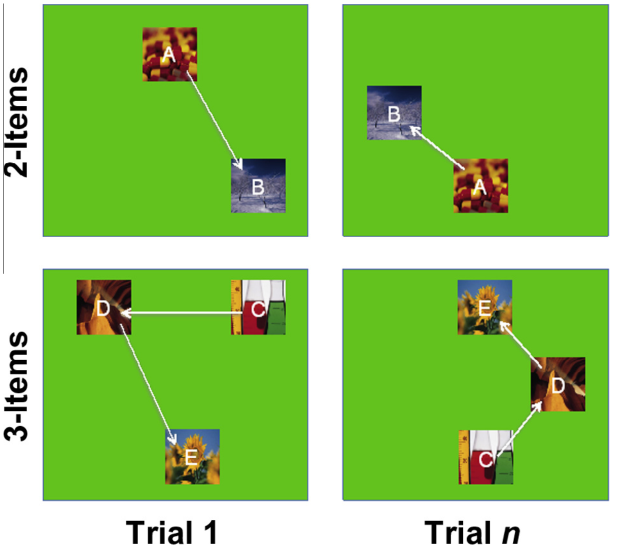

Fig. 1. Cognitive Imitation Task. The 2- and 3-item cognitive task is shown. Different picture items appear simultaneously in different spatial positions on a touch-screen. Items' positions change from trial to trial, but the order in which they must be touched remains constant. The objective is to touch each item (regardless of spatial position) in a specific order to find "Jumping Man," a 5-s video of a man doing a backward summersault accompanied by music.

Consequently, this task is unique in allowing us to precisely identify how different WM demands may constrain imitation and emulation.

In Experiments 1 and 2, the Cognitive Imitation Task was used to assess two specific responses: Order (copying the target serial order, e.g., A → B → C) and Multi-Tap (double-tapping one of the pictures on the screen, e.g., A → B → B → C). These two responses were executed on 2-picture lists (corresponding with low WM demands) as well as on 3-picture lists (corresponding with high WM demands). Imitation was defined as copying both responses used by the experimenter to achieve a goal, in effect, achieving the demonstrated goal (e.g., "Jumping Man") in the *same* manner demonstrated. Emulation was operationalized as copying (or failing to copy) one of the two responses demonstrated to achieve a goal, that is, achieving the demonstrated goal using idiosyncratic means (Wood, 1989). Using these measures, we evaluated whether different WM demands (low [2-picture] lists vs. high [3-picture] lists) affected the *amount* as well as the *type* of information that children copied from a model. Although it was expected that more children should imitate on 2-picture lists with low WM demands than on 3-picture lists with high WM demands, it was not entirely clear how WM might constrain the performance of children who emulate. One possibility is that emulators will ignore the response that is most likely to be causally meaningless (i.e., Multi-Tap) and will copy only the response that is most likely to be causally necessary (i.e., Order). Alternatively, high WM demands might lead children to copy the least complex response (i.e., Multi-Tap) because it imposes fewer WM demands and to ignore the more difficult response (i.e., Order) because it imposes the most WM demands.

Experiment 1

Method

Participants

A total of 69 children (31% racial/ethnic minority) completed training and testing: 36 3-year olds (18 girls and 18 boys, M_{age} = 40.85 months, SD = 3.76) and 33 4-year olds (14 girls and 19 boys, M_{age} = 54.09 months, SD = 3.32). An additional 10 3-year olds and 7 4-year olds were enrolled in the study but excluded due to experimenter error ($n = 16$) or lack of assent from a child ($n = 1$). All participants were recruited and tested in the Smithsonian Institute's National Zoological Park or the National Museum of Natural History. Informed consent was collected from participants' parent(s) or legal guardian(s). Informed assent was obtained from participating children immediately prior to testing. The institutional review boards of The George Washington University and the Smithsonian Institution approved all aspects of the study.

Materials

The Cognitive Imitation Task described above (cf. Fig. 1) was presented on a 54.6-cm screen from a Macintosh desktop computer with a Magic-Touch detachable screen. List items used throughout testing were composed of color photographs (3.81×5.08 cm). New lists of pictures were used in each condition. During testing, four unique 2- and 3-picture lists were used. The chance of responding correctly on the first trial on a 2-picture sequence is .50, and .17 on a 3-picture sequence. These differences in chance probabilities (corresponding with difficulty) and the amount of information (2 vs. 3 pictures that needed to be held in WM) served as the basis for the distinction between low WM (2-picture) and high WM (3-picture) demands.[2] However, because pictures do not disappear after correct responses, these probabilities do not take into consideration the fact that—although very rare (<1%)—children can make "backward errors" such as A → B → A (Subiaul et al., 2007). Backward errors are impossible to make in 2-picture lists because the trial ends once children touch all of the pictures on the screen.

Procedures

Training. All children were trained on a 3-picture list on the computer task prior to testing. Training procedures have been described extensively in previous publications (Subiaul et al., 2012). Briefly, these procedures mirror those described below for Baseline. The computer recorded all responses automatically.

Testing. Once children satisfactorily completed Training, they were tested in two conditions: Baseline (no demonstration) and Social (demonstration). Each condition consisted of a low WM 2-picture list ($n = 2$) and a high WM 3-picture list ($n = 2$) per child. This resulted in a 2 (Age: 3- or 4-year olds) × 2 (Condition: Baseline or Social) × 2 (WM: low [2-pictures] or high [3-pictures]) design. Pictures used for Testing were different from those used in Training.

Baseline (trial-and-error learning). This condition was used to establish a baseline rate for Order, Multi-Tap, and Both responses, that is, the probability of generating any of these target responses randomly by chance. In this condition, children were provided with a maximum of 20 trials. However, testing ended 5 s after children touched all of the pictures on the screen in the target order. In this condition, children were provided with no prompts, hints, or instructions besides being told that the game was to find "Jumping Man," a 5-s video of a man doing a backward summersault accompanied by music. To do so, they needed to first "find picture number one." Once children found picture number one, they were asked, "What's next?" Having found the second picture in the sequence, they were asked, "What's last?" When children made a mistake, the experimenter said, "Oops! That's not right. Let's try again. Remember, start with picture number one." The same procedure was repeated until children responded to all pictures in the target order.

Social. The model demonstrated two target responses, Order and Multi-Tap, three consecutive times. Specifically, the experimenter faced children and said, "It's my turn first—watch me," and then proceeded to touch each item on the screen in the correct sequence (i.e., Order). While responding to pictures in sequence, the model touched one of the pictures twice (i.e., Multi-Tap). Every effort was made to make this Multi-Tap response salient and intentional. To do so, the model touched the target picture, pulled back their hand, looked at the children, and touched the picture a second time before touching the last picture. Having touched all items on the screen, Jumping Man played (~5 s) and the experimenter clapped, looked at the children, smiled, and said, "Yay! I found Jumping Man!"

[2] Here, 3 pictures, as opposed to 4 pictures, were chosen because the addition of the Multi-Tap corresponded with a fourth response that children needed to encode.

Following this demonstration, the model said, "Now, it's your turn. Remember, start with picture number one." Trials ended 5 s after children touched all of the pictures on the screen.

In contrast to Training and Baseline, where children needed to respond to pictures in a specific order and had a maximum of 20 trials, in the Social condition children received nondifferential reinforcement. This allowed us to assess whether children responded to all of the pictures in the sequence demonstrated (i.e., Order) and/or touched any of the pictures multiple times (i.e., Multi-Tap). As a result, all Social conditions consisted of a single trial.

To prevent carryover from the Social condition to the Baseline condition, testing in Baseline preceded testing in the Social condition. We also presented children with the easiest task before the more difficult task. As such, testing proceeded in the following order: 2-picture Baseline → 3-picture Baseline → 2-picture Social → 3-picture Social.

Measures

There were three dependent measures: Order, touching all of the pictures on the screen in the target order on the first trial (binomial code: 1 = correctly responded to all items on Trial 1, otherwise 0), Multi-Tap, touching any of the pictures on the screen two or more times (binomial code: 1 = Multi-Tap, otherwise 0), and Both, generating both Order and Multi-Tap responses described above (binomial code: 1 = Order + Multi-Tap, otherwise 0). Examples are provided in Table 1. The Order measure captures the copying of a specific ordinal rule that involves touching three pictures in a specific sequence. In contrast, the Multi-Tap measure captures the copying of a motor response that involves touching one or more pictures two or more times. In the Social condition, where participants saw a demonstration prior to making a response, generating both responses as defined above (Order + Multi-Tap) is referred to as imitation. Copying only Order or only Multi-Tap as defined above is referred to as emulation. Although opinions vary widely on these distinctions (Heyes, 2012; Subiaul, 2007; Whiten et al., 2009; Zentall, 2006), our operationalization of imitation and emulation for this study is not fundamentally different from that made originally by Wood (1989) and Tomasello and colleagues (Nagell et al., 1993). In general, we follow the convention that imitation refers to achieving a goal or result (i.e., Jumping Man) using the *same* method demonstrated by the model (Carpenter & Call, 2002; Whiten et al., 2009). In contrast, emulation involves achieving the model's goal or the same result using idiosyncratic means (Tomasello, 1990; Whiten & Ham, 1992; Wood, 1988), that is, selectively copying/ignoring some of the model's responses. Children who failed to copy any of the target responses as we defined them were classified as making "Neither" response. Table 1 summarizes the methods and procedures as well as the measures used in Experiments 1 and 2. Examples are included for illustrative purposes.

Table 1
Summary of methods, procedures, and measures.

		Measures			
Condition Reinforcement	Maximum trials	Order (touching all pictures in the target order)	Multi-Tap (touching one of the pictures more than once, independently of the target order)	Both (Order + Multi-Tap) (touching one of the pictures more than once and touching all pictures in the target order)	Neither (failing to touch one picture more than once and touching all pictures in the target order)
Baseline Differential	20[a]	A, B, C	A, A, C[b]	A, B, B, C	A, C[b]
		Emulation		Imitation	
Social Nondifferential	1	A, B, C	A, A, C, B	A, B, B, C	C, A, B

[a] In the Baseline condition, children were given a maximum of 20 trials to discover the target order of pictures. Once they touched all pictures in the target order, children moved on to another condition.

[b] In Baseline, trials ended when children touched a picture in the incorrect order. Given this constraint, children could not generate the following responses: B → A or C → B. Likewise, trials ended if children generated the following response: A → B → A.

Results

A preliminary analysis of all the data (Experiments 1 and 2) revealed that sex did not significantly correlate with the generation of any of the measures in the Baseline or Social condition, $r(166) < .15$, $p > .05$ (Pearson correlation). Given these results, we did not evaluate sex further. Because all of the data were nominal, we used nonparametric tests throughout. All analyses are two-tailed.

Because our main hypothesis makes specific predictions of children's learning in the Social condition, we first tested whether significantly more children generated any of the target responses (Multi-Tap, Order, or Both) in the Social condition than in the Baseline condition. Results showed that children generated at least one of the target responses significantly more in the Social condition than in the Baseline condition (all $ps < .05$). This was true for 2- and 3-picture sequences (all $ps < .05$) as well as for 3- and 4-year-olds (all $ps < .05$, Wilcoxon signed ranks task). Given the robust evidence for social learning, we now focus on children's performance in the Social condition. Results are summarized in Table 2.

If WM constrains imitation, then more children should imitate—copying both target responses (Multi-Tap and Order)—on 2-picture sequences than on 3-picture sequences. A Wilcoxon signed ranks test showed that, proportionally, significantly more children copied both target responses on 2-picture sequences ($M = .48$) than on 3-picture sequences ($M = .28$), $Z = -3.30$, $p = .001$, consistent with the WM hypothesis. As expected, this effect was more pronounced for 3-year-olds than for 4-year olds. Specifically, 3-year-olds ($Z = -2.98$, $p < .01$), but not 4-year olds ($Z = -1.63$, $p = .10$), copied both responses significantly more on 2-picture sequences than on 3-picture sequences. A Kruskal–Wallis test showed that whereas the number of 3- and 4-year-olds did not differ when copying both Order and Multi-Tap on 2-picture sequences, $\chi^2(1) = 1.13$, $p = .29$, significantly more 4-year-olds than 3-year-olds copied both responses on 3-picture sequences, $\chi^2(1) = 6.92$, $p < .01$. Results are summarized in Fig. 2.

If WM constrains emulation, then more children should emulate—copying either the Multi-Tap or Order target responses (but not both)—on 3-picture sequences than on 2-picture sequences.

Table 2
Proportions of children generating at least one of the target responses (Order, Multi-Tap, or Both) in the Baseline and Social conditions.

		3-year-olds		4-year-olds	
		Baseline	Social	Baseline	Social
Experiment 1: No instructions	2 items	.5	.86	.48	.88
	3 items	.36	.53	.12	.7
Experiment 2: Copy Multi-Tap Instructions	2 items	.5	.67	.58	.88
	3 items	.33	.63	.29	.79
Experiment 2: Ignore Multi-Tap Instructions	2 items	.58	.71	.56	.88
	3 items	.25	.25	.16	.68

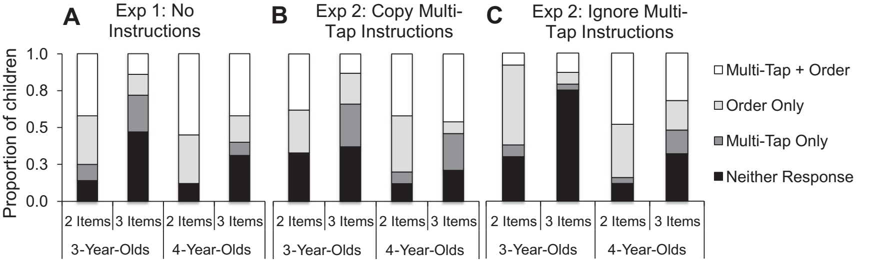

Fig. 2. Proportion of children in the Social condition making a target response. (A) Experiment 1. (B) Experiment 2, Copy Multi-Tap instruction group. Children were instructed to copy the Multi-Tap response during the Social demonstration. (C) Experiment 2, Ignore Multi-Tap instruction group. Children were instructed to ignore the Multi-Tap response during the Social demonstration.

A Wilcoxon signed ranks test showed that, proportionally, the number of children emulating—copying either Order or Multi-Tap—did not significantly differ between 2- and 3-picture sequences ($Z = -.76$, $p = .45$). There were also no significant differences between 3- and 4-year-olds' rate of emulation on 2- and 3-picture sequences (all *ps* > .30, Kruskal–Wallis test). Regardless of list length or age group, there was no difference between the number of children who emulated or imitated (all *ps* > .05, Wilcoxon signed ranks test using a Bonferroni correction).

Are children either imitators or emulators regardless of WM demands? If individual differences in WM capacities determine whether children imitate or emulate, then there should be a significant positive correlation between imitating on 2- and 3-picture lists and a significant positive correlation between those emulating on 2- and 3-picture lists. A Spearman correlation showed that children who imitated on 2-picture lists also imitated on 3-picture lists ($r = .42$, $p < .01$). However, children who emulated on 2-picture lists were not necessarily the same children who emulated on 3-picture lists ($r = .22$, $p = .14$) even after those who failed to copy any of the target responses on 3-picture lists were excluded ($r = .29$, $p = .10$). Although there were no significant differences between the number of children emulating on 2- and 3-picture sequences, 57% (39/68) of children emulated at least once across list lengths.

Do differing WM demands between 2- and 3-picture lists bias children to copy (or ignore) the Multi-Tap response? To answer this question, we analyzed only those children who emulated on 2- or 3-picture lists ($n = 39$). Given the small *n*, we collapsed across age groups. A Wilcoxon signed ranks test showed that significantly more children copied Order than Multi-Tap on 2-picture lists (Order mean = .59, Multi-Tap mean = .10, $Z = -3.66$, $p = .001$) but not on 3-picture lists (Order mean = .28, Multi-Tap mean = .31, $Z = -.21$, $p = .84$). This effect was driven by the fact that twice as many children copied the Multi-Tap response on 3-picture lists than on 2-picture lists ($Z = -2.31$, $p = .02$) and significantly less children copied Order on 3-picture lists than on 2-picture lists ($Z = -2.83$, $p < .01$).

Discussion

These results are consistent with the hypothesis that WM constrains whether children imitate or emulate. Specifically, the results show that preschool-age children can identify, encode, and subsequently copy two distinct target responses as demonstrated, including one that was fairly opaque (e.g., Multi-Tap) when WM demands are low (i.e., 2-picture list) but less so when they are high (i.e., 3-picture list). The fact that children imitate more—copying both demonstrated responses—on 2-picture lists than on 3-picture lists is consistent with various studies demonstrating that on object-based tasks children are more likely to copy two causally unrelated responses than three of them (e.g., Bauer, 1992; Bauer & Hertsgaard, 1993; Dickerson et al., 2013). Perhaps a more interesting question that has not been studied extensively is whether WM also constrains emulation. An analysis of emulators revealed that WM, in fact, affected what children copied on 2-picture lists as well as on 3-picture lists. Specifically, emulators copied Order more on 2-picture lists than on 3-picture lists. However, significantly more children copied the Multi-Tap on 3-picture lists than on 2-picture lists. This result suggests that when children emulate, they are making a trade-off between which response is the most *important* to copy and which response they are *capable* of copying when task demands exceed individual WM capabilities.

Alternatively, it is possible that children's performance is best characterized as mimicry, defined as blindly generating demonstrated responses without any understanding of the model's goal (Zentall, 2006). Arguing against this possibility is the performance of the many children who copied both responses when tested on 2 picture lists but then eliminated one of these responses (usually Order) when tested on 3 picture lists. Rather than indicating a lack of understanding of the model's intention, switching from copying both responses to copying one specific response represents, at the very least, an adaptive—rational—reaction to increasing WM load. Nonetheless, children might have alternated their responses because no explicit instructions were given as to which of these responses was most important to copy.

In an effort to address this alternative possibility, Experiment 2 sought to bias children in the Social condition. In effect, we sought to anchor children's social learning with instructions specifying whether they should copy or ignore the Multi-Tap response. To that end, Experiment 2 used instructions similar to those employed by Lyons et al. (2007) in order to bias social learning toward copying only the Multi-Tap.

Experiment 2

Method

Participants

An additional group of children were recruited for this experiment. A total of 97 children (42% racial/ethnic minority) completed training and testing: 48 3-year-olds (26 girls and 22 boys, $M_{age} = 42.44$ months, $SD = 3.15$) and 49 4-year olds (21 girls and 28 boys, $M_{age} = 54.29$ months, $SD = 3.36$). An additional 6 3-year-olds and 2 4-year-olds were enrolled but excluded from the study due to experimenter error ($n = 4$) or lack of assent from the children ($n = 4$). All participants were recruited as in Experiment 1.

Procedures

Training and Testing. Procedures were the same as in Experiment 1 with the following exception. Children were randomly assigned to one of two instruction groups: Copy Multi-Tap or Ignore Multi-Tap.

Baseline. This condition was the same as in Experiment 1.

Social. Before Testing on 2- or 3-picture lists, the experimenter read one of two scripts to children:

> *Copy Multi-Tap*. Children were read the following script: ''You can touch some pictures two times. When I touch pictures two times, it's to help us find Jumping Man, okay?'' After this point, the model said, ''Watch me!''[3]
>
> *Ignore Multi-Tap*. Children were read the following script: ''You don't have to touch pictures two times. When I touch pictures two times, it's a silly little thing that doesn't help us find Jumping Man, okay?''[4] After this point, the model said, ''Watch me!''

Results

As in Experiment 1, the hypothesis we tested in Experiment 2 makes specific predictions of children's learning in the Social condition. Consequently, we first tested whether significantly more children generated one or more of the target responses (Multi-Tap, Order, or Both) in the Social condition than in the Baseline condition across instruction groups. Using a Wilcoxon signed ranks test, results showed that, regardless of instruction type, 4-year old children generated the target Order, Multi-Tap, or Both responses significantly more in the Social condition than in the Baseline condition (all $ps < .05$). This was true for 2- and 3-picture lists (all $ps < .05$). Three-year olds in the Ignore and Copy Multi-Tap Instruction Group, generally, generated more target responses in the Social than in the Baseline condition (c.f., Table 2), though this difference did not reach statistical significance (all $ps > .05$). Using a Kruskal Wallis Test, a direct comparison of 3- and 4-year old's performance showed no significant differences in each age group's rate of generating the Multi-Tap or Order response for either 2- or 3-item lists (all $ps > .05$). However, 4-year olds in the Ignore Multi-Tap instruction group generated Both (Multi-Tap + Order) responses more than 3-year olds when tested on 3-item lists, $p = .042$, but not 2-item lists, $p = .86$ (corrected for multiple comparisons using the Bonferroni procedure). Given these results, all subsequent analyses focus on children's performance in the Social condition.

First, we evaluated whether children in the Copy Multi-Tap instruction group copied the Multi-Tap response more than children in the Ignore Multi-Tap instruction group. Second, we evaluated whether

[3] The experimenter verified that children had correctly heard and understood the instructions by asking, ''Do you have to touch pictures two times?'' Fully 100% of 3- and 4-year-olds answered ''yes'' with either a verbal or nonverbal response.

[4] The experimenter verified that children had correctly heard and understood the instructions by asking, ''Do you have to touch pictures two times?'' Fully 95% of 3-year-olds and 100% of 4-year-olds answered ''no'' with either a verbal or nonverbal response.

children in the Ignore Multi-Tap instruction group copied Order more than children in the Copy Multi-Tap instruction group. A Mann-Whitney U test was used to compare the number of children copying only the Multi-Tap response or only Order in the two instruction groups. Correcting for multiple comparisons using the Bonferroni correction,[5] results showed that, regardless of age and list length, instructions to either copy or ignore the Multi-Tap did not significantly affect the number of children copying only the Multi-Tap or Order response (all $ps > .05$). The two instruction groups did not differ in the proportion of children copying Both target responses, $\chi^2(1) = 1.61$, $p = .21$ (Kruskal–Wallis test). Results are summarized in Fig. 2.

We then compared the performances of children in Experiments 1 and 2 to see whether instructions significantly changed children's performance in Experiment 2. Specifically, we looked at the proportion of children emulating and imitating as well as the proportion of children copying only Multi-Tap or Order across list lengths and age groups. There were no statistically significant differences for any of these measures or groups (all $ps > .20$, Kruskal–Wallis test).

Discussion

While generally depressing the overall performance of 3-year olds in the Social condition, instructions to either copy or ignore the Multi-Tap response had no effect on the number of children imitating/emulating or on the number of children copying only the Multi-Tap response or Order. Results from Experiment 2 replicated those of Experiment 1 and showed that children largely ignored the instructions given. As in Experiment 1, children imitated/emulated depending on list length and WM load.

General discussion

The current study makes two significant contributions to the debate concerning why children imitate in some tasks but emulate in others. First, results demonstrate that imitation fidelity depends on whether WM demands were low (e.g., 2-picture lists) or high (e.g., 3-picture lists). These results are consistent with earlier serial tasks with objects where performance was best for pairs (Bauer, 1992; Bauer, Hertsgaard, Dropik, & Daly, 1998) and older children performed better than younger children (Dickerson et al., 2013). Second, and perhaps most importantly, WM demands appear to have also affected what children copied when they emulated. On the one hand, exceeding WM demands may have imposed nonspecific constraints on emulation, in which case children would have copied Order and Multi-Tap responses with equal frequency. On the other hand, exceeding WM demands may have imposed specific constraints on emulation. Results are consistent with this latter hypothesis; emulators overwhelmingly copied Order more when WM demands were low than when they were high. Conversely, more children copied the Multi-Tap response when WM demands were high than when demands were low. This trade-off, not coincidentally, corresponded with the information processing demands of what was copied; the more difficult and complex response (Order) was copied on 2-picture sequences with low WM load, whereas the easier and less complex response (Multi-Tap) was copied on 3-picture sequences with high WM load. This pattern of response also argues against the possibility that children failed to attend or neglected one response over the other.

The current study was not designed to specifically address either social or causal hypotheses for imitation versus emulation. Nonetheless, the results are difficult to reconcile with some social models of emulation arguing that children order goals hierarchically such as the goal-directed imitation (or GOADI) hypothesis (e.g., Bekkering, Wohlschlager, & Gattis, 2000; Wohlschlager, Gattis, & Bekkering, 2003). According to the GOADI hypothesis, children prioritize some goal-directed behavior(s) over others depending on the salience of the model's action(s) and/or end state(s). Although children's responses alternated between copying Order and Multi-Tap, this pattern of results cannot be easily explained by the GOADI hypothesis because the model's responses and the end result, Jumping Man, were identical across studies. Even when children's attention was focused on the

[5] p Value $\times$ 4 comparisons.

Multi-Tap—highlighting that response as the primary goal (i.e., Experiment 2)—children's performance did not differ from what was reported in Experiment 1, where no instructions were provided.

Theories arguing that children's imitation performance is best explained by different motivations to affiliate or "be like" others (e.g., Meltzoff, 2007; Nielsen, 2006; Over & Carpenter, 2012; Uzgiris, 1981), or from a desire to conform to group norms (Kenward, Karlsson, & Persson, 2011), have similar difficulties explaining the performance of children in the current study because children received the same training by the same experimenter throughout. Moreover, instructions did not seem to have any effect on children's imitation fidelity. Instead, both younger and older children appear to have ignored these instructions and continued to imitate or emulate as they had done when no instructions were provided.

Results are more consistent with research suggesting that in the artifact domain children show a tendency to encode all responses as causally necessary (Lyons et al., 2007, 2011). As we have already mentioned, this effect was modulated by different WM constraints associated with younger age groups, as reported by a number of other researchers (Dickerson et al., 2013; McGuigan, Whiten, Flynn, & Horner, 2007). This is not to say that children's attributions of goals, intentions, or norms do not contribute to imitation performance. There is ample evidence showing that they do. But we question whether social accounts *alone* can explain all instances of imitation, including overimitation, as some strong proponents of the social account have conceded (Nielsen, Moore, & Mohamedally, 2012). Instead, results from the current study demonstrate that WM constrains not only imitation but emulation as well. It is an open question whether WM similarly constrains all forms of social learning, including gestural, motor–spatial, and vocal imitation (Subiaul, 2010), and whether these constraints are constant across development. Regardless, the current results make clear that WM constraints represent a new factor that may help to explain both the versatility and uniqueness of children's social learning.

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