دراسة أثر الوظائف التنفيذية على رسم الصور المألوفة والغير مألوفة لدى الأطفال الصغار

Investigating the effect of executive functions on young children's drawing of familiar and novel pictures

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قسم علم النفس – كلية العلوم الاجتماعية جامعة الإمام محمد بن سعود الإسلامية

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ملخص الدراسة:

هذه الدراسة تتعلق بدور الوظائف التنفيذية، وتحديدًا علاقة التحكم المثبط (IC) والذاكرة العاملة (WM) بالقدرات المعرفية ممثلة بالقدرة على الرسم لدى الأطفال الصغار الذين تتراوح أعمارهم بين 3.5 إلى 5.5 سنة تقريبًا، حيث إن نموهم العقلي أمر محوري لفهم تعلم الطفل وسلوكه الاجتماعي. وقد استخدمت الدراسة عددا من المهام لقياس كلا من التحكم المثبط والذاكرة العاملة، ومن هذه المهام: مهمة النهار/الليل، ومهمة العشب/الثلج، واختبار السيد خيار. وهذه المهام والاختبارات تم إجراؤها على العينة مع مهام رسم محددة. وقد شارك في الدراسة 95 طفلاً قام كل منهم بتلك المهام والاختبارات على جلستين لتقييم قدراتهم الإدراكية في رسم أشكال مألوفة مثل شكل الانسان وأخرى غير مألوفة مثل شكل الكلب. وتم رصد درجات الرسومات من حيث الدقة التمثيلية والانحراف عن الأشكال المرسومة. واتضح من نتائج تحليل الانحدار وتحليل المتغيرات الوسيطة أن التحكم المثبط (IC) مؤثر في رسم الأشكال المألوفة، في حين كانت الذاكرة العاملة (WM) مؤثرة في رسم الأشكال غير المألوفة. وأظهرت النتائج حساسية التحكم المثبط والذاكرة العاملة في معرفة مهمة الرسم، مما يؤكد أهمية الوظائف التنفيذية في القدرات المعرفية المختلفة للأطفال. وهذه النتائج يمكن أن تساهم في فهم النمو العقلي للأطفال، وبالتالي تقديم تطبيقات مهمة لفهم تأثير الوظائف التنفيذية على التعلم والسلوك الاجتماعي لدى الأطفال.

الكلمات المفتاحية: رسم الطفل، التحكم المثبط، الذاكرة العاملة المواضيع المألوفة والغير مألوفة

Investigating the effect of executive functions on young children's drawing of familiar and novel pictures

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Abstract:

This study investigates the role of executive functions, specifically inhibitory control (IC) and working memory (WM), in relation to children's drawing abilities, focusing on young children aged approximately 3.5 to 5.5 years, since their mental development is pivotal to understanding child learning and social behaviour. Tasks employed to measure IC and WM included the Day/Night task, the Grass/Snow task, the Mr. Cucumber test, administered along with specific drawing tasks. The research involved 95 participants who undertook the tasks and tests, administered in two sessions, to assess their cognitive abilities in drawing familiar subjects (human figures) and unfamiliar ones (dogs, rarely drawn by children). The drawings were scored for representational accuracy and for deviation from human figures. Regression and mediation analyses revealed that IC predominantly influenced the drawing of recognizable men, while WM was crucial for drawing non-human-like dogs. The results demonstrate the sensitivity of IC and WM to the familiarity of the drawing task, emphasizing the importance of executive functions in various cognitive abilities of children. The findings provide significant insights into children's mental development and so have crucial implications for understanding the impact of executive functions on learning and social behaviour in children.

Keywords: child drawing, inhibitory control, working memory, familiar and unfamiliar subjects.

Introduction

For many years a central concern of cognitive psychologists has been the workings of the executive functions (EFs). These are a key high-level part of the human mental apparatus that controls and organises human thought and behaviour (Zelazo et al., 2008). They are usually seen as including a number of distinct components such as inhibitory control (IC), working memory (WM), and planning (Gross & Grossman, 2010). These are different kinds of cognitive ability which coordinate information, and produce goal-directed actions (Anderson, 2002). This article is mainly concerned with the first two.

One important type of human individual targeted by psychological research is the young child, whose mental development it is clearly important to understand (Anderson, 2002). EFs and their development have therefore become an important research area in relation to young children because of how they affect social behaviour and learning (Davidson et al., 2006). For instance, they are related to the school readiness of a child (Cameron, Brock, Murrah et al., 2012). Within this area, currently it is found that two of the EFs, IC and WM, are especially relevant to a number of mental and academic abilities of children.

IC is the ability to stop an unsuitable but perhaps habitual response or to disregard distracting irrelevant information (Simpson and Riggs, 2006). This EF is important as a support for children's cognitive abilities such as self-regulation and understanding of other people's minds, the physical world, written language, and maths (Montgomery & Koeltzow, 2010). Many of these activities however have barely started in very young children or are hard to detect. One that lends itself more readily to study is drawing, which children do from an early age, is visible, and requires some use of EFs.

WM is also required in many different mental activities which often have behavioral manifestations, such as speaking, reading, and solving math problems. WM is described as a cognitive system with multiple subcomponents used to store, and work with, information for short periods of time in the mind (Baddeley, 2000). Most experts agree that WM includes a storage mechanism called short-term memory and processing capacity to regulate and coordinate the information stored, if needed (Engle et al., 1999). Once again it seems likely that drawing would require some use of WM.

Where drawing is a focus of attention, of course, common sense suggests that some physical skill is needed, apart from the mental activity of EFs. Indeed, it has been shown that, in order to draw skillfully, pre-school children need such skill, which is under the guidance of fine motor control (FMC) (Lange-Küttner, 2008). FMC manages the use of small muscles (e.g. in hands and fingers) to move in a precise and refined manner. This is required for daily activities, such as feeding oneself, getting dressed, writing and of course drawing (Cools, De Martelaer, Samaey & Andries, 2009). FMC also involves making use of visual stimuli from the environment (Korkman, Kirk & Kemp, 2007), e.g. to complete a jigsaw puzzle (Sorter & Kulp, 2003).

At the present time an area at the forefront of child psychology research is, then, that of what the exact relationships are of IC and WM with child drawing skill and how they relate to the role of

FMC in the development of that skill. That is what the present paper addresses.

Literature on IC, WM and FMC in relation to children drawing

The study of child drawing has a considerable history since the seminal work of Luquet (1913). It ranges across a number of interesting areas, covering both drawing something from memory and drawing something in view, and familiar drawing (of something that is often drawn, such as a person) versus unfamiliar drawing (of something rarely if ever drawn before, such as a dog). The current study addresses a particular issue concerning the role of EFs and FMC when familiar or unfamiliar drawing is done from memory by preschool children. This is best approached through examining recent studies in this area.

The relationship between EFs in general and drawing has quite a long history. Indeed, the connection is so well established that drawing is sometimes included in the set of measures used to quantify EF as a general construct (Fuhs, Nesbitt, Farran & Dong, 2014). The precise nature, extent and route of the contributions of specific component EFs such as IC and WM, however, are still in the process of being elucidated.

Miyake and colleagues (2000) proposed that, when children learn to draw, several specific EFs play a role, including IC, WM and attention shifting. Barlow, Jolley, White and Galbraith (2003) suggested that children need IC in order to improve the figurative realism of their drawing by inhibiting their habitual way of drawing the target, so as to advance to better drawing. They also need to continually monitor changes that they make to their habitual way of drawing a target, in case they do not produce improvement, which implies the involvement of WM. Hence, they indicate that somehow WM and IC need to work together to yield development in measured drawing skill.

Panesi and Morra’s (2016) study found evidence that IC and WM are both related to what they call the drawing flexibility of young children, when drawing unfamiliar subject matter (e.g. a dog). Note that what is termed 'unfamiliar' in this discussion is the drawing of a dog: there is no suggestion that dogs themselves are unfamiliar to children. Young children have been found to manage this task by exploiting the schema they already have for drawing something they often draw, such as a person. Drawing flexibility (DF) is then the extent to which they are able to draw a dog without over-reliance on the schema they already possess for drawing a person (e.g. the dog is drawn standing on four legs, not two). In a regression analysis of predictors of the dog drawing scores, both WM and a variable they call EF, but which was predominantly IC, emerge as having significant direct effects on drawing skill (measured as DF), in the presence of age and a motor coordination measure. However, this study did not analyze results for drawing a familiar subject, nor consider possible mediation effects. Nevertheless, this study amplified that of Morra (2005) that found that WM was relevant to any drawing task requiring modification of a schema, including drawing a familiar subject (such as a person) performing a novel action.

Following a separate line of enquiry, Simpson et al. (2019) were also concerned with the development of drawing skills in preschool children. However, their focus was more on drawing familiar subjects and on the role of IC rather than WM, in relation to FMC.

Their concern was with existing proposed accounts of how IC might affect drawing, including one, the Behavioral Inhibition account, that predicts a direct effect of IC on (familiar) drawing and another, the Motor Development account, that predicts an effect of IC mediated through FMC. Simpson et al. (2019) in fact found that FMC mediated the relationship between IC and drawing skill of young children, with respect to the degree of figurative representation (FR) and detail when drawing familiar subject matter. IC then had no direct effect on drawing skill, thus supporting the second account. However, WM and unfamiliar drawing were absent from this study. This prompted the present study which aims to combine the designs of Simpson et al. and Panesi and Morra so as to clarify the impact of both IC and WM, directly or mediated, in both familiar and unfamiliar drawing tasks.

Aims of the study

This study aims to forge a link between the previous research of Simpson et al. (2019) and that of Panesi and Morra (2016). Both concerned the development of drawing skills in preschool children. Simpson et al. (2019) suggested that Fine Motor Control (FMC) mediates the relationship between Inhibitory Control (IC) and drawing skill of young children, with respect to their figurative representation and detail when drawing familiar subject matter (i.e., a house and a person). In contrast, Panesi and Morra's (2016) data suggested that IC and Working Memory (WM) are related directly to the drawing flexibility of young children, when drawing unfamiliar subject matter (a dog).

Here we bring these two approaches together (See Figure 1) to examine the relationship between FMC, IC, and WM on the one hand and two measures of drawing on the other: drawing a familiar subject (a person) scored for figurative representation (FR), and drawing an unfamiliar subject (a dog) scored for drawing flexibility (DF).

We intend to answer two research questions:

- Does FMC mediate the relationship between WM and drawing skill of both types (figurative representation and drawing flexibility) in the same way as has been shown previously for IC and figurative representation? Or, is this mediating relationship between IC and FMC *specific* to this component of executive function, and so does not extend to WM?

- Is there a *direct* and specific relationship between IC and drawing flexibility when drawing unfamiliar subject matter (the dog), but no direct relationship of IC with figurative representation when drawing familiar subject matter (the person – as shown in Simpson et al., 2019)? The rationale here would be that children have to inhibit their drawing schema of a person in order to draw a dog, but have nothing to inhibit when drawing a person. It is the need to inhibit a specific schema that we propose creates the direct relationship between IC and drawing a dog.

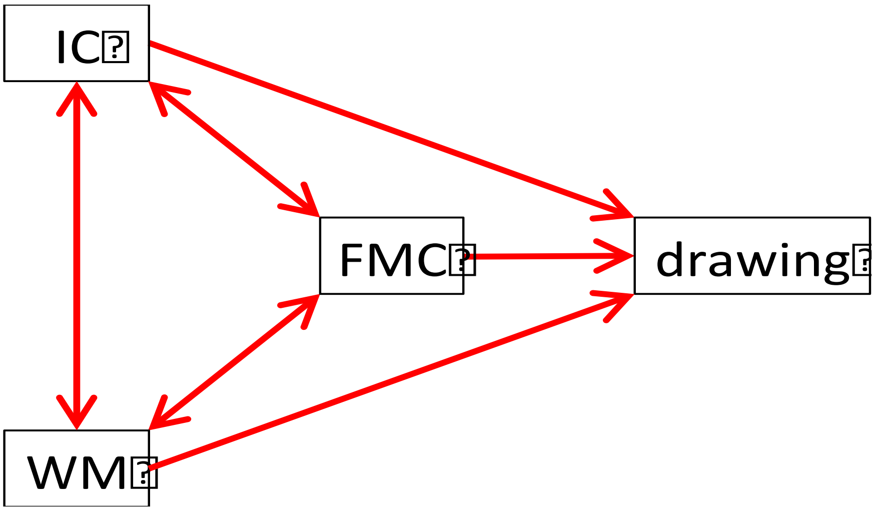

Figure 1. Potential direct and mediated relationships between variables (measured controlling for age and gender).

Method

Participants

95 children participated in this study, with age range from 3.5 to 5.5 years with half between 3.5-4.5 years and half between 4.5 and 5.5 years. The minimum age selected was 3.5 years, because younger children cannot draw a dog, while 5.5 years was the oldest age, to ensure that we obtained variance in accuracy on the tasks we used to measure IC (Petersen, Hoyniak, McQuillan, Bates & Staples, 2016). Participants were recruited from preschools and nurseries in Colchester, UK. All spoke English as their first

language, and none were reported as having any behavioral or learning difficulties (based on teachers' reports). The sample was of mixed social background and was predominantly white.

As Table 1 shows, all key measures appear to be recording reasonable variance with means distant from the ends of the measurement scale.

Table 1. Descriptive statistics (N=95, Male 48%)

Variables	Minimum	Maximum	Mean	*SD*
Inhibitory control	0	32	22.3	10.52
Working memory	0	17	8.9	3.75
Fine motor control	0	12	7.8	3.41
Figurative representation	.5	5	3.6	1.30
Drawing flexibility	0	9	2.9	2.50
Age (in months)	41	66	55.1	7.93

Design

In the current study, a within-subjects correlational design was used. The two drawing measures were the dependent variables: figurative representation when drawing a familiar subject (a person) and drawing flexibility when drawing an unfamiliar subject (a dog). The independent variables were IC, FMC, WM, Age and Gender.

***Task* selection**

IC Tasks

Two age-appropriate Response Inhibition tasks were used in the current study, the Day/Night task and the Grass/Snow task (Petersen et al., 2016). In this study, children in the Day/Night task were asked to say *sun* when the researcher showed them a moon card and to say *moon* when they were shown a sun card, so the Day / Night Task requires a verbal response. In the Grass/Snow task they were asked to point to the sun card when the experimenter said *moon* and point to the moon card when the experimenter said *sun*, so it involved a gestural response. Although the Grass/Snow task involves a motor response, as children need to point towards the cued picture, this was deemed to be minimal as pointing is an easy task for 3-year-olds. Hence it was not felt that the nature of this task biased the instrument in favour of detecting any influence of FMC.

WM task – Mr. Cucumber test

In this task (adapted from Panesi & Morra, 2016), the child sees a picture of the outline of a potato shaped figure, to which circular colored stickers have been attached. The picture is displayed for a limited time, and after it is removed, the child is asked to add stickers in the same places to a blank outline of the figure. The positions where stickers may be added include on the mouth, eyes, antennae or ears, each side of the nose or on the nose etc. In all, there are 14 possible sticker locations. Stickers are of uniform color in any one trial. Up to 24 pictures are offered, containing between one and eight added stickers, with three trials at each number of stickers. The display times for pictures are: 1-5 stickers, 5 seconds; 6 stickers, 6 seconds; 7 stickers 7 seconds; 8 stickers, 8 seconds (Panesi and Morra, 2016).

The main differences between our implementation of this task and that of previous studies are as follows. First, we displayed the picture stimuli using PowerPoint, rather than on paper, so as to more easily and accurately control the display time. Second, we asked the children to actually place stickers on a blank outline rather than just point to where the stickers had been in the previously seen picture. This was done partly to make the task more interesting for the child, since young children are known to enjoy placing stickers on things. This procedure also made scoring easier and more objective. Furthermore, since the test was of memory for where the stickers had been placed, rather than how many had been placed, we supplied the correct number of stickers to be placed in each trial. With finger pointing there was always the possibility that they would point at too many or too few positions, which again makes scoring more complex. Finally, we also controlled the sticker color to be the same on each trial rather than mixed colors. This was because the test was of memory for sticker position, not of color combined with position, and keeping color uniform within each trial meant that there could be no confusion in the child’s minds about what exactly they were supposed to be remembering.

WM task – Digit span task

In this task, the researcher reads aloud random sequences of numbers which the child is asked to immediately repeat back, in the same order. Following Gathercole and Adams (1993) we prepared random sequences of 2, 3 etc. digits. Due to the age of the participants, we excluded the digit 0 and used only those from 1 to 9.

FMC tasks

FMC was measured using the Peabody Developmental Motor Scale (PDMS-2) (Wang, Liao & Hsieh, 2006). The Fine Motor Quotient was obtained through six selected age-appropriate tasks from the PDMS-2, involving (Grasping a marker, Lacing a string, Touching fingers, Dropping pellets, Buttoning a strip and Building steps - see Table 2).

Drawing tasks

The two drawing tasks were also taken from earlier studies of children's drawing skills. Two free drawing tasks were included, in which children were asked to draw from memory a male human figure (Cox & Parkin, 1986) and a dog figure (Panesi & Morra, 2016). The first of these was considered a familiar subject for children and the second of these is regarded in the literature as an unfamiliar subject (in the sense that although children may be familiar with dogs, they do not usually draw them).

Task Materials

The following materials were used for the tasks involved in the study:

1. Drawing tasks: Plain A4 paper, pencils.
2. IC Day/Night task: a flip-book, which contained 16 pictures, half of the sun in a day sky and half of the moon in a night sky (See Figure 3).
3. IC Grass/Snow task: two pictures, one of the sun in a day sky, the other of the moon in a night sky (See Figure 3).
4. FMC Motor Control Task (MC): materials from the Fine Motor Quotient of the Peabody Developmental Motor Scale – Second Edition (PDMS-2, Wang et al., 2006). The materials included a button strip and stopwatch. In addition to this, there were six colored square blocks made of wood, a strip of card with 6 holes in it, a shoe lace, marker, paper

(8.5x11 in.), small bottle and 10 food pellets (See Figure 4).

5. WM Task, Mr Cucumber: laptop running Microsoft PowerPoint, images of the potato man with stickers placed in various positions, paper copies of the blank outline of the potato man, colored circular stickers. Locations of stickers were selected by numbering each potential location from 1 to 14 from top to bottom of the figure. Next, we selected combinations of locations using random numbers generated by The Research Randomizer (https://www.randomizer.org/) . For the level of the test where four sticker locations had to be presented, for example, this software was used to select three sets of 4 numbers randomly selected from the range 1-14.
6. WM Task, Digit span: sheets of random digits in sequences of 2, 3, 4 etc. Again, The Research Randomizer was used to generate three random sequences of each length, from the range 1-9.

Procedure

The tasks were administered over two sessions – morning and afternoon or up to two weeks apart. A total of 12 tasks were administered to each child in two sessions: two Drawing tasks, two IC tasks, six MC tasks and two WM tasks. Two researchers (E1 and E2) collected the data: one administered the tasks and the other recorded children’s responses (apart from the drawing tasks, which were scored later). Within the first session, tasks were presented in the order: first Drawing Task (Draw a Person), IC Task (Grass/Snow), WM Task (Mr Cucumber), three FMC Tasks (Grasping a marker, Lacing a string, Finger touching). In the second session: second Drawing Task (Draw a Dog), IC Task (Day/Night), WM Task (Digit Span), and three FMC tasks (Dropping pellets, unbuttoning a strip, Building steps).

All 12 tasks were presented in a fixed order (See Table 3). Children were tested individually in a room adjacent to their main classroom or in a quiet corner of the classroom itself during playtime. Each child was seated across the table from the first experimenter (E1) and was told that they were going to play some fun games. The second experimenter (E2) sat next to the child and recorded the child’s responses.

Drawing Tasks

For each Drawing task, a piece of plain A4 paper and a pencil were placed on the table in front of the child. Session 1, for the Human-figure task, following Morra and Panesi (2016), children were asked to draw a man, with no time limit, with the instruction, "Can you draw a picture of a man". If they asked any questions about how to draw it, they were asked to “…just do your best drawing”. Session 2, for the Dog task, the researcher gave the child a white A4 sheet and a pencil and invited the child to draw a dog, with no time limit.

IC Tasks

The Day/Night and Grass/Snow procedure were taken from Simpson and Riggs (2009). Session 1, in the Grass/Snow task, E1 explained that they were going to play a ‘silly game’ in which the child would have to point to two pictures. Children were shown the sun and moon pictures and asked to name them. E1 then explained that in the game they should point to the sun picture when she said, “moon”, and to the moon picture when she said “sun”. The child was explicitly told not to point to the named pictures. E1 then ‘talked children through the rules’ by saying the two names and getting them to point to the appropriate picture (e.g., “…so when I say sun, can you show me which picture you have to point to?”) confirming that they were correct or correcting them, if necessary, by referring to the rules. Children then received four practise trials (order: Sun, Moon, Sun, Moon) with feedback. If, for example, the child pointed to the moon when the experimenter said “sun”, the experimenter confirmed that this was the correct response. If, however, the child pointed to the sun, the experimenter said that this was wrong because moon was correct. Children next received 16 test trials in the same pseudorandom order (ABBABAABBABAABAB) and with no feedback. E2 coded children’s responses.

In Session 2, an identical procedure was used with the Day/Night task. E1 first explained the rules using the sun and moon pictures. The four practice and 16 test trials were presented using a flip-book, which contained 20 pictures. Another experimenter recorded responses.

MC tasks

This included six tasks from PDMS-2 (See Table 2 and Figure 4), which were presented in a fixed order (See Table 3). Three of these tasks were presented in the first session and three of these tasks were presented in session 2. The tasks were administered as follows. In Session 1, Grasping a marker (numbered 22 in PDMS-2): a marker and paper were placed in front of the child on the table and E1 asked the child to make a mark. E2 observed how the child held the marker. Lacing (numbered 39-40 in PDMS-2): E1 placed a string on the table and showed the child a strip containing 6 holes. E1 asked the child to "Watch me lace", then E1 held the string and strip clearly so that the child could see exactly what she was doing. E1 began to lace by placing the string top down through the first hole, and up through the second hole, and down through the third hole. E1 showed the child the final result, and then removed the string from the strip, and placed these two items on the table in front of the child. Children were instructed to "Do it like I did". Children were allowed to take as much time as they needed to complete the task. Touching finger (numbered 26 in PDMS-2): E1 demonstrated touching her thumb with each finger successively at a rate of one touch per second. Children were then instructed to do the same thing.

In Session 2, Dropping pellets (numbered 41-42 in PDMS-2): E1 placed a bottle without a cap and 10 pellets on the table in front of the child. E1 would instruct the child by saying "Put the food in the bottle as fast as you can". The child was also told to place one pellet in the bottle at a time. Unbuttoning buttons (numbered 23 in PDMS-2): the button strip was placed in front of the child by E1 and the child was instructed to unbutton the strip as fast as they could. Building steps (numbered 51-52 in PDMS-2): E1 placed 6 cubes on the table in front of the child and made sure her hands were clearly visible to the child so that they could see exactly what was going on. E1 demonstrated building steps with three cubes on the bottom row, two cubes on the next row and finally one cube on top. E1 left the steps for a short while in front of the child for them to examine. The steps were then disassembled and the cubes were placed in front of the child. The child was then instructed to build the steps like E1 did.

WM tasks

Session 1 used the Mr Cucumber task. First the child was introduced to the task with the words "This is Mr Cucumber. Say hello to Mr Cucumber. He likes to play tricks sticking colored stickers on different parts of his body. The game is, can you remember where he sticks them?" The child was then given two practice trials, placing the stickers while the original picture remained in view, with researcher feedback. This was needed to ensure that the child fully understood what was required and was corrected if, for example, they systematically placed stickers on the left when they should be on the right hand side of the picture. This was followed by two practice trials where the original picture was not in view while the stickers were placed, again with feedback and, if necessary, reshowing of the original picture.

In the test itself, the stimuli pictures of the cucumber figure, with stickers attached, were displayed using Microsoft PowerPoint set to show a picture for the correct number of seconds, and then progress to a blank slide to await researcher input to advance to the next picture. The test began with three items where a single sticker had been added to the outline and progressed through three items with 2 stickers, up to 8 stickers. The researcher gave no feedback concerning correctness during the test. The test was discontinued when a child failed all three items at a level. After each picture was displayed, but not before, the researcher handed to the child the correct number of stickers to place on the blank outline picture for that particular trial. This occupied one or two seconds, which served to reduce the likelihood of the child being able to exploit iconic memory, rather than working memory, to complete the task. In order to counter the objection that some significant amount of FMC was involved in placing the stickers, children were not put under time pressure to place the stickers, and were allowed to move them if the first place they put a sticker was not quite the one they intended.

Session 2 used the Digit span task. First each child was given two practice sequences of two digits with feedback from the researcher on their performance. Next, the researcher said, "Now we will begin” and said a sequence of two digits. The child responded and E2 recorded whether the response was correct or not. E1 then said the next sequence of two digits and the child responded. If the child was correct on both sequences, the researcher then progressed to a sequence with three digits. If the child was incorrect on both, the test stopped. If the child was correct on one sequence of the two, a third sequence of two digits was spoken. If the child was correct on that, the researcher then progressed to a three digit sequence. If the child was incorrect, the test stopped. The same procedure was followed for sequences of three digits and longer sequences, until the child failed to produce two correct responses at a given sequence length.

Scoring

The male Human-figure task was scored according to Cox and Parkin’s (1986) Human-figure scale (Figure 2). This is a five-point scale: (1) scribble, (2) distinct forms, (3) tadpoles, (4) transitional figures, or (5) conventional figures (scored 1-5). It thus scores the drawing for the point at which it lies on the developmental scale of drawing found in young children, from scribble to representing something like a person: Figurative Representation (FR).

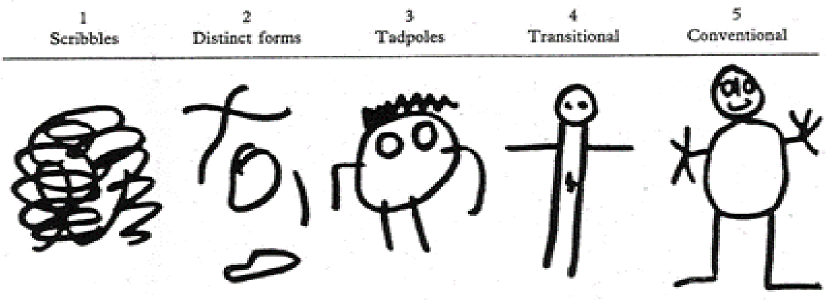

Figure 2. Cox and Parkin's (1986) Human-figure scale

For the Dog task the list of 13 features (See Table 4) was used from Morra and Panesi (2016). These scoring criteria had been devised so that drawing flexibility could be scored as independently as possible from general drawing development. One point was awarded for each feature in which a dog drawing was different from that of a child's human figure drawing (except Feature 4, which was scored 1 point in case 4a and a half point in case 4b). This yields a maximum possible score of 13 for Drawing Flexibility (DF).

For the IC tasks a total score out of 32 is given to each child depending on the correct responses given in both IC tasks. The FMC tasks were scored ranging from 0 to 2, and these scores are then added together to form the total fine motor score for each child (maximum of 12 for all tasks). The MC tasks were all scored by E2.

Finally in the Mr Cucumber task one point was given for each consecutive level on which a child got at least two items correct, and one third of a point was given for each correct item above that level. This means that if a child got two trials right at the level of one sticker, then one of the three at the two sticker level, then two at the three sticker level, and none at the four sticker level, they would be awarded only ⅔ of a point at that third sticker level, not 1. Their score overall would be 2. The maximum possible that can be scored is 8 points.

In the Digit Span task, the child’s digit span score was the longest sequence length at which the child produced two correct responses. There is no fixed possible maximum score, but the maximum achieved was 13.

Table 2. Tasks used to measure FMC.

The Fine Motor Quotient	
The Grasping Sub-scale	Visual-motor integration Sub-scale
Grasping a marker (task 22)	Lacing a string (task 58)
Finger touching (task 26)	Dropping pellets (task 74)
Unbuttoning a strip (task 24)	Building steps (task 75)

Table 3. Task order

Session 1	Session 2
1 Draw Person	7 Draw dog
2 Grass/Snow	8 Digit span
3 Mr Cucumber	9 Day/Night
4 Grasping a marker (task 22)	10 Dropping pellets (task 74)
5 Lacing a string (task 58)	11 Unbuttoning a strip (task 24)
6 Finger touching (task 26)	12 Building steps (task 75)

Table 4. The list of dog's features for scoring DF

1. Whole dog's figure length > height
2. Head connected to body along horizontal axis
3. Pointed or elongated face
4a. Face details (nose at the end of the head)
4b. Face details (cat/bunny face or mouth farther than eyes from the trunk)
5. Pointed or hanging ears
6. Whiskers
7. Tongue extending out of mouth
8. Trunk length > height
9. Hair on body/legs
10. Four vertical legs
11. Paws
12. Tail
13. Dog's objects (collar, leash, or muzzle)

Figure 3: The Day/Night Task.

Figure 4: PDMS-2 Test Materials

Reliability

Two judges independently scored the drawings. The Pearson correlation between their scores was .900 for the drawing of a man and .845 for the dog drawings. This we took as a sign of high reliability and the means of the two scores for each person on each measure were used in the statistical calculations.

Results

Correlation results

Apart from gender, all the other IVs are significantly and positively related to drawing scores for both man and dog, and indeed to each other (Table 5). However, the extent to which all these correlations are simply due to development, i.e. that IC, WM and FMC all correlate with age as well as drawing measures, is unclear from a correlation analysis such as this. Rather than interpreting the correlations in detail, we therefore move to analyses where the mutual effects of the IVs amongst themselves are taken into account, and especially the influence of age is controlled for.

Table 5. Correlations

		Gender	IC total	WM total	FMC total	FR drawing a man	DF drawing a dog
Age in months	*r*	-.120	.529	.470	.566	.741	.670
	p	.246	<.001	<.001	<.001	<.001	<.001
Gender	*r*		-.017	-.131	-.083	-.122	-.120
	p		.873	.207	.424	.238	.248
IC total	*r*			.488	.834	.537	.353
	p			<.001	<.001	<.001	<.001
WM total	*r*				.506	.357	.445
	p				<.001	<.001	<.001
FMC total	*r*					.490	.338
	p					<.001	.001
Drawing a man	*r*						.628
	p						<.001

Regression and Mediation results

Since the research questions concern not just simple effects but effects mediated through other variables, it was necessary to perform some form of analysis that could calculate such effects. Following the recommendations of Shrout and Bolger (2002), a regular linear regression analysis was performed, combined with a mediation analysis, employing a bootstrapping procedure to calculate the confidence interval around an indirect effect (i.e., the path from the independent variable to the dependent through a mediator). If zero falls outside this interval, significant mediation is regarded as being present. The SPSS macro written by Preacher and Hayes (2008) was used to perform all the required multiple regression calculations and those for mediation requiring bootstrapping.

In both analyses (Tables 6,7) there is a strong positive effect of age on the DV and no significant effect of gender. The effect of age is widely found, including in Simpson et al (2019) and Panesi and Morra (2016), and is to be expected in a study where the variables all develop with age.

In the analyses of familiar picture drawing, IC has a highly significant effect on FMC but FMC fails to have a significant effect on the DV, figurative representation, and no significant mediation of IC through FMC is found. IC does however have a significant direct effect on FR. No effects of WM are significant.

In the analyses of unfamiliar picture drawing, IC again has a highly significant effect on FMC but FMC again fails to have a significant effect on the DV drawing flexibility, and no significant mediation of IC (or WM) through FMC is found. IC has no other significant effect on DF. WM however has a significant direct effect on DF.

Table 6. Familiar drawing. Mediation analyses with FR as dependent

Effect and Path	Variables	*B* Coefficient	*SE*	*t*	*p*
IV to MV (Path a)	IC → FMC	.2336	.0223	10.50	<.001**
	WM → FMC	.0782	.0596	1.31	.193
MV to DV (Path b)	FMC → FR	-.0498	.0500	-0.99	.323
Total Effect of IV on DV (Path c) = Direct + Indirect	IC → FR	.0282	.0106	2.67	.009**
	WM → FR	-.0206	.0283	-0.73	.468
Direct Effect of IV on DV (Path c')	IC → FR	.0398	.0157	2.53	.013*
	WM → FR	-.0167	.0286	-0.59	.560
Partial Effect of Control Variables on DV	Age → FR	.1090	.0142	7.70	<.001**
	Gender → FR	-.1103	.1713	-0.64	.521
				Bias corrected 95% confidence interval‡	
Indirect Effect of IV on DV through MV (Path ab)	IC→ FMC → FR	-.0116, -.0112‡	.0114‡	-.043 to .008	
	WM→ FMC → FR	-.0039, -.0041‡	.0061‡	-.029 to .003	

‡Bootstrapped estimates (1000 resamples)

Table 7. Unfamiliar drawing. Mediation analyses with DF as dependent.

Effect and Path	Variables	*B* Coefficient	*SE*	*t*	*p*
IV to MV (Path a)	IC → FMC	.2336	.0223	10.50	<.001**
	WM → FMC	.0782	.0596	1.31	.193
MV to DV (Path b)	FMC → DF	-.1406	.1071	-1.31	.193
Total Effect of IV on DV (Path c) = Direct + Indirect	IC → DF	-.0133	.0227	-0.59	.559
	WM → DF	.1223	.0608	2.01	.048*
Direct Effect of IV on DV (Path c')	IC → DF	.0195	.0337	0.58	.564
	WM → DF	.1332	.0612	2.18	.032*
Partial Effect of Control Variables on DV	Age → DF	.2008	.0303	6.62	<.001**
	Gender → DF	-.2443	.3668	-0.67	.507
					Bias corrected 95% confidence interval‡
Indirect Effect of IV on DV through MV (Path ab)	IC→ FMC → DF	-.0328, -.0325‡	.0225‡	-.081 to .011	
	WM→ FMC → DF	-.0110, -.0103‡	.0139‡	-.061 to .004	

‡Bootstrapped estimates (1000 resamples)

First RQ

- Does FMC mediate the relationship between WM and drawing skill of both types (figurative representation and drawing flexibility) in the same way as has been shown previously for IC and figurative representation? Or, is this mediating relationship between IC and FMC *specific* to this component of executive function, and so does not extend to WM?

The mediation underlying drawing of familiar and unfamiliar subjects is similar, but not in the way assumed by the question. There is in fact no significant mediation of either IC or WM through FMC with either kind of drawing. Indeed, FMC has no significant relationship with either drawing measure, in the presence of the other variables in the model (only as a simple correlation). Therefore, the two components of the executive function (IC and WM) behave in a similar way in both drawing tasks with respect to mediation.

In this respect, it remains to be explained however why there was no mediation of FMC between IC and the FR drawing measure as in Simpson et al. (2019). In fact, IC is strongly related to FMC in both tasks, but the lack of a link between FMC and either of the drawing measures makes mediation impossible. In particular the familiar drawing task is closest to Simpson et al. (2019), and the lack of mediation in that appears to negate the conclusion that that paper reached, that there is support of the Motor Development account of the effect of IC.

Explanation

One potential explanation could be design factors. In particular, Simpson et al. (2019) was a study in which WM was not included while it clearly was in the present study. In fact, however, running the present analysis of the familiar task omitting WM does not alter the result. IC remains a predictor of FMW and a direct predictor of FR, but not a predictor of FR mediated via FMC.

Possibly influential also could be the measures chosen to quantify FMC. Those in the present study were slightly fewer and arguably a little less demanding but that does not really explain the lack of relationship with drawing measures (Present study: Lacing a string; Finger touching; Building steps; Unbuttoning a strip; Grasping a marker; Dropping pellets. Other study: Lace a string; Touch fingers; Build a pyramid; Build diagonal-pyramid; Button strip; Cut a circle; Cut a square; Fold paper).

Third we might seek an explanation in differences in the sample of participants from those in Simpson et al. (2019). However, the number was similar (95 vs 100), and also the source, both being drawn from the UK, Colchester area. The age range in the present study however started a little higher than that of the source studies, at 41-66 months compared with 36-54 in Simpson and 36-73 in Panesi and Morra. However, running analyses on our data just using younger children from our sample did not alter the substantive findings. Nevertheless, it remains possible that the missing earlier 5 months of participants creates the contrasting findings.

Whatever the reason, our study seems to contradict Simpson et al.'s (2019) conclusion that the Motor Development account of how IC affects FR is correct, since that depends on the mediation of IC through FMC. Instead, our finding supports the Behavioural Inhibition account or perhaps the Symbolic Competence account (which predicts a link mediated through symbolic understanding, but, since I did not measure symbolic understanding, in the context of this study the link would appear to be also direct).

Second RQ

- Is there a *direct* and specific relationship between IC and drawing flexibility when drawing unfamiliar subject matter (the dog), but no direct relationship of IC with figurative representation when drawing familiar subject matter (the person – as shown in Simpson et al., 2019)? The rationale here would be that children have to inhibit their drawing schema of a person in order to draw a dog, but have nothing to inhibit when drawing a person. It is the need to inhibit a specific schema that we propose creates the direct relationship between IC and drawing a dog.

Aside from the issue of mediation through FMC, the role of IC and WM is indeed different in the two drawing tasks, but not as suggested above. IC was found just to have a direct effect on FR but not DF; in reverse, WM had a direct effect on DF but not FR.

Explanation

The involvement of WM with DF but not FR was expected from Panesi and Morra (2016). Drawing an unfamiliar subject requires a child to retrieve from long term memory a related schema (of a person, when drawing an animal) and to use WM as a think pad to alter it into the picture required to be drawn. Drawing a familiar subject like a man only requires retrieving from longer term memory the required related schema of a man, which needs no alteration in WM.

It is harder to explain why IC has a direct effect in the familiar subject drawing but not the unfamiliar task. Still, it is possible to argue that even in drawing the familiar subject there is a need for a child to control their tendency to scribble and produce something that is minimally figurative, or indeed to inhibit the habit of just drawing what they did last time and not trying to improve it. That then could explain the presence of a direct IC effect in drawing the person. However, it remains unexplained why IC is not present also, and maybe more strongly, when drawing the dog, where there is again a need to inhibit scribbling and an even greater need to inhibit just drawing a person rather than changing it to suit a dog.

Possibly we could find an explanation in the detailed administration of the tasks. The present study separated the drawing of the man and the drawing of the dog into separate sessions and with various measures of the other variables in between. However, it seems (although the account of method is not fully explicit on this point) that drawing the dog followed directly after drawing a person in the same session in Panesi and Morra (2016). If so, that would surely produce a stronger prepotency of the human schema in the latter study than the former, through a priming effect, and hence a greater application of IC would be needed to combat it in the latter study when drawing a dog. Hence it would not be surprising to find IC having a stronger effect on drawing quality (DF) in Panesi and Morra than the present study.

An altogether different answer could be that the flexibility required to draw a dog is not in fact a matter of inhibiting the person schema, i.e. resisting using it, but rather of altering and adapting it to suit a dog. That then is not pure inhibition, but falls in what many treat as a component of the executive function separate from IC and WM, called cognitive flexibility (CF) (Zelazo et al.

2008). CF has been defined as "the readiness with which one can selectively switch between mental processes to generate appropriate behavioral responses" (Dajani and Uddin, 2015 p571). A typical measure is a card sorting task where the rule for sorting is changed in the middle (e.g. from sorting by shape of what is on the card to sorting by color). Thus, the emphasis is not on a person being able to stop thinking or doing something but rather to be able to change in a suitable way, based on what has gone before and new circumstances. This then perhaps fits the dog drawing scenario better than IC. Hence it could account for why measures of IC do not always relate to DF, and requires studies where the CF of participants is measured rather than their IC.

Conclusion

This study appears to underline that finding, and so theories that depend on those findings, can be quite fragile in child psychology, especially where very young participants are involved. While the study confirmed the importance of IC in a familiar drawing task (cf. Simpson et al., 2019) and of WM in an unfamiliar one (cf. Panesi and Morra, 2016), it failed to replicate mediation of IC affecting drawing skill via FMC in the former (as Simpson et al., 2019, found), or a significant role for IC affecting drawing skill at all in the latter (as Panesi and Morra, 2016, found).

Clearly more studies are needed in this area and, from our discussion above, we recommend three aspects to be closely examined. First, it needs to be ascertained just how critical for obtaining a particular result are the children at the very lowest end of the drawing scale, at 36-41 months. Second, the effect of drawing a human immediately before drawing a dog versus at some distance in time before, with other tasks in between, needs to be experimented, so as to quantify the priming effect in each case and the possible impact which that has on the effect of IC on drawing quality. Third, there needs to be research using the EF of cognitive flexibility as a variable, especially, but not exclusively, in relation to unfamiliar drawing. Arguably, based on the adaptive requirements of an unfamiliar drawing task, and indeed the adaptation needed by anyone trying to improve their drawing even on a familiar task, CF could prove as important as IC or WM in understanding the earliest development of child drawing.

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