Executive Function Tasks

Experiment Details

PI: Dr Michelle Ellefson[1]

CoPIs: Prof Claire Hughes[1], Florrie Ng[2], Qian Wang[2]

[1] University of Cambridge [2] The Chinese University of Hong Kong

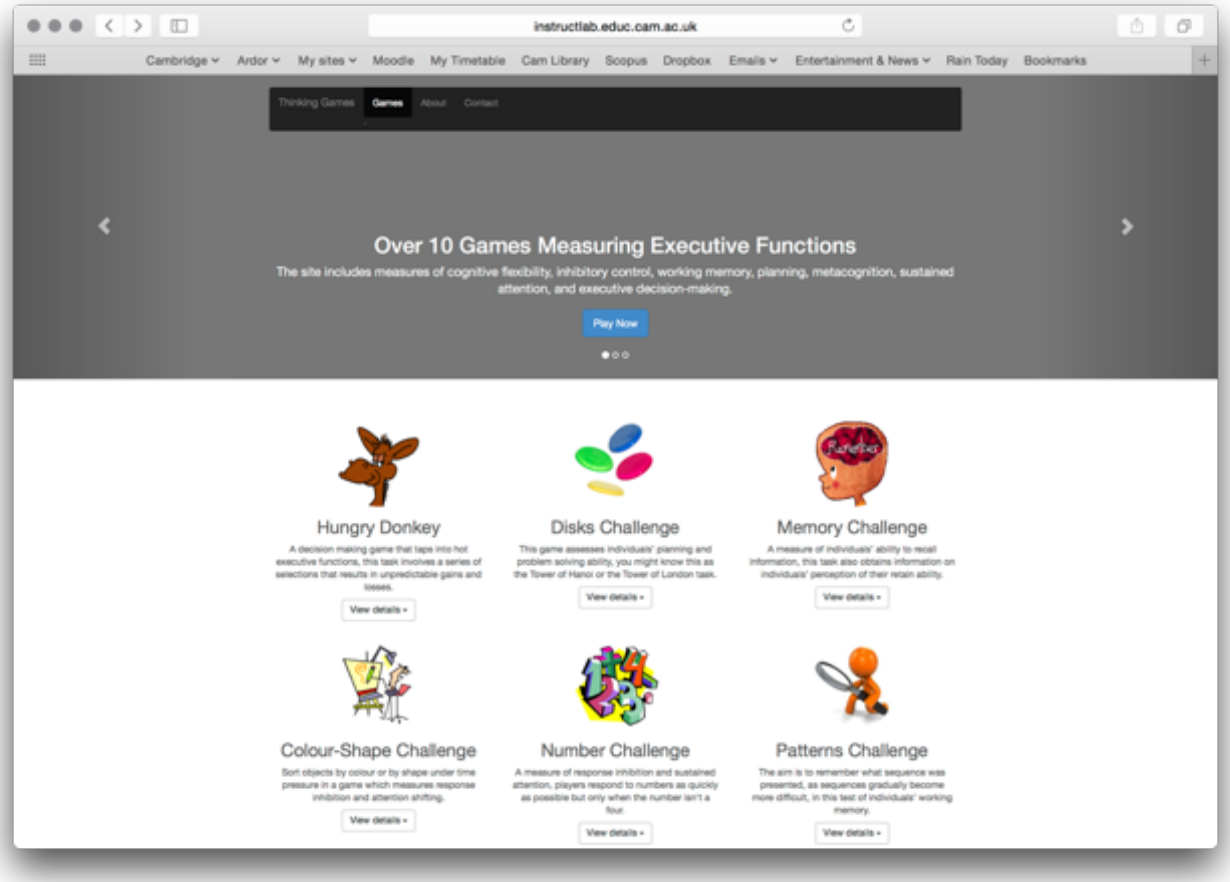
UNIVERSITY OF CAMBRIDGE

香港中文大學 The Chinese University of Hong Kong

These EF tasks are available from Dr Michelle Ellefson's Thinking Games Website: http://instructlab.educ.cam.ac.uk/TGsummary/

Details of the structure of each of the EF tasks used for this study are included in this document. Additional task and information are available on the Thinking Games site.

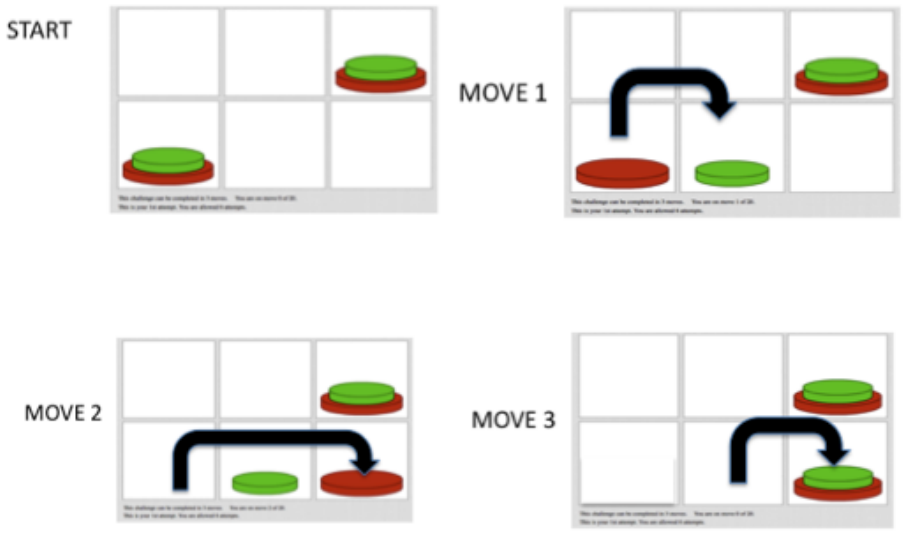
Contact Dr Michelle Ellefson (mre33@cam.ac.uk) for more information or if you are interested developing a collaboration that uses these tasks.



The Disks Challenge

Overview

- The disks challenge is a Tower of Hanoi task and is a game that assesses individuals' planning and problem solving ability (similar to the Tower of London.
    - It examines future oriented planning skills **(Welsh, 1991)** as this task requires the player to pre-plan the configuration before moving the disks.
- In this task, participants are shown a picture of three disks (small, medium and large) and are required to arrange their disks in a few moves as possible to match the picture, following the rule that only one disk can be moved at a time and a larger disk cannot be placed on a smaller disk.
    - More advanced stages include four disks of four differing sizes (extra-small, small, medium, large)
- Participants move a disk by clicking on it and then clicking on the box where they want it to go.
    - Only one disk can be moved at a time
    - Large disks are not allowed to be placed on small disks
    - Participants can have up to 20 moves to solve a problem
- An accurate solution to a tower task is to move arrange the disks in as few moves as possible
- When participants are able to provide an accurate solution to the same tower task twice in a row, then they move to a more difficult tower task
    - Participants have up to six attempts to solve a tower correctly twice in a row
- This challenge ends when the participant is unable to solve a given tower with the fewest possible moves twice in a row within six attempts



Key References

Welsh, M (1991) Rule-guided behavior and self-monitoring on the tower of Hanoi disk-transfer task. *Cognitive Development*, *6*, 59-76.

Bishop, D.V.M., Aamodt-Leeper, G., Creswell, C., McGurk, R., & Skuse, D.H. (2001). Individual differences in cognitive planning on the Tower of Hanoi task: Neuropsychological maturity or measurement error? *Journal of Child Psychology and Psychiatry*, *42*, 551-556.

Additional Research Summaries

- The Tower of Hanoi task has been used with patients with frontal lobe damage. These participants performed significantly lower than controls highlighting the role of the frontal lobes when completing such tasks **(Goal & Grafman, 1995).**
- Poor performance has also been recognised in individuals with autism spectrum disorder **(Ozonoff, Pennington & Rogers, 1991).**
- Studies have also shown that performance on the disks challenge is unrelated to IQ **(Welsh, Pennington & Grossier, 1991).**
- **Huizinga et al (2006)** examined performance in four age groups (7 to 21 years) and found a developmental increase in performance. Working memory and shifting were two common factors that emerged from confirmatory factor analysis. Working memory and shifting showed developmental change through to adolescence.

Instruction Slides

Instructions

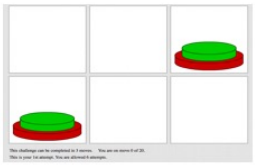
In this Challenge you are to try to move the disks so that they are the same as the picture on the top in as few moves as possible.

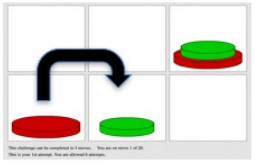
However, you can **only place smaller disks on larger disks** and you will not be able to place larger disks onto smaller ones.

You have **up to 20 moves** for each one. Let's try one for practice.

START 

Always move the disks in the second row to the lower right-hand box so that it matches the top picture exactly.

START 

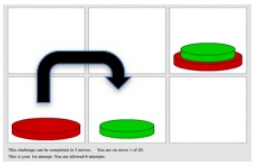
MOVE 1 

To move a disk, you have to first raise it by clicking the disk once, and then click on the box where you would like to place the disk.

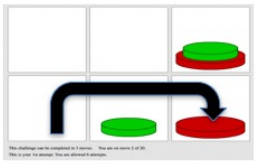
START

Remember, your goal is to move the disks of the second row so that they match the top row in as few moves as possible.

MOVE 1



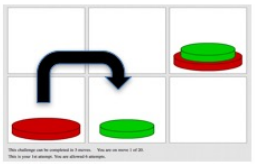
MOVE 2



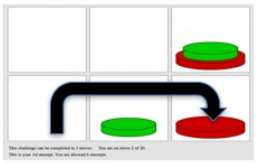
START

Remember, your goal is to move the disks of the second row so that they match the top row in as few moves as possible.

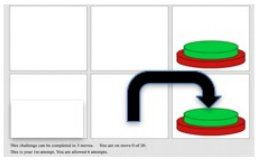
MOVE 1



MOVE 2



MOVE 3



FINISH !!

You are Ready to Start the Disks Challenge

Now, we're going to start the Challenge.

Remember, you can **only place smaller disks on larger disks**.

your goal is to move the disks so that they match the top picture in **as few moves as possible**.

You must solve each one **with the fewest moves two times in a row** before you get to move onto a harder one.

On the next screen, click on the ***Start Game*** button to start.

Experiment Structure

- Six 3-ring problems, including 2-, 3-, 4-, 5-, 6-, and 7-move problems and three 4-ring problems, including 7-, 11-, and 15-moves (see Welsh, 1991 page 64)

- For each problem, participants have up to six attempts to solve the problem with the minimum number of moves (i.e., 2, 3, 4, 5, 6, and 7).

- For each attempt, participants have up to 20 moves before they are moved onto the next attempt

- In order to move onto the next problem, participants need to solve the problem in the minimum moves on two consecutive trials – once they have two consecutive trials at the minimum moves, they go to the next one (i.e., they don't need to use up all six attempts)

- If a participant does not solve the problem in the minimum number of moves within their six attempts, then the challenge ends.

- Feedback

    - When the participant first solves the problem in the minimum number of moves, then when they see the next attempt they should see "Let's try it again"

    - When the participant does not solve the problem in the minimum number of moves, then when they see the next attempt they should see "Let's try it again with fewer moves"

- Notes about the programming

    - When an illegal move is attempted, the disk is placed in the central location

    - The illegal move isn't counted towards the total moves to complete in the program in terms of reaching ceiling on the task until the participant moves the object to a location. For example, if the participant tries an illegal move then follows it with the most efficient move it is possible for them to complete the task in the correct number of moves. This will be a programming glitch for now – we'll need to adjust that when analyzing the data. (although that error is recorded so that we know if it happens, and how many times, so we can add it to the score later)

- Participant responses collected

    - Disc moved (along with location)

    - Timing for each disc move (RT, in msec); plus total time to complete the attempt

    - Running tally of moves

Feedback Slides

Great work! Can you get it right again? Try to go faster this time. 	Excellent! You got two right in a row. Now we're going to try a harder one. 
Good Try! You got the answer. Let's go again – try to do it this time with fewer moves. 	You didn't get it that time, But you can try again. 
You have finished the Disks Challenge!  You're a star!	

Common Implementation Issues

- Participants must solve each one twice in the fewest number of moves before they can move to the more challenging level.
- Some participants may complete the disk arrangement but in the incorrect box (i.e. not the box directly under the example) which will restrict them from going on to the next level- just remind participants of this rule.

- The task stops when participants do not reach criteria to move to the next level. They get up to six attempts which sometimes participants find tedious so the researcher must provide lots of encouragement.

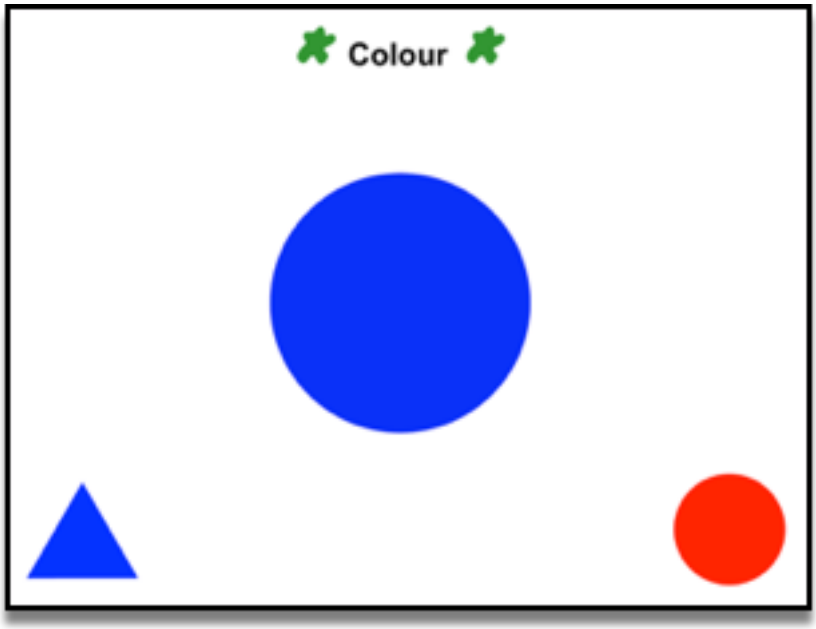
- Taking longer doesn't always mean that the participants are struggling

- Participants may vary dramatically on the time taken to complete this task.

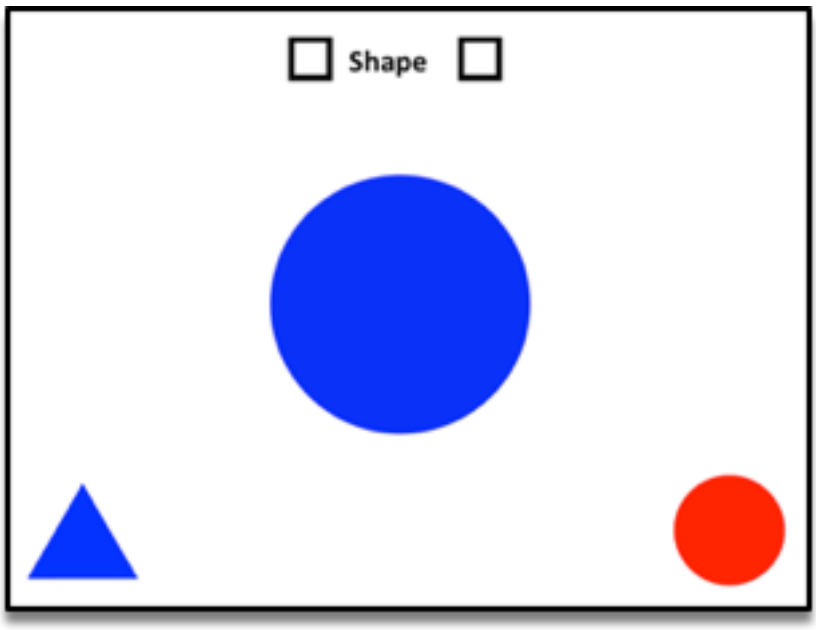
The Figures (Colour-Shape) Challenge

Overview

- The colour-shape challenge is a measure of response inhibition and attention shifting.
- The goal of this game is to sort objects by colour or by shape under time pressure.
- On the screen an object is presented (either a triangle or a circle which is either red or blue). The participant is required to sort this object by shape or by colour (the rule is indicated at the top of the screen).
- To complete the task, the individual must match the target shape to one of the two shapes presented beneath the target object as quickly as possible.
- There are four different sets of trials
    - One for shape only
    - One for colour only
    - Two for shape and colour



This is an example of a COLOUR trial



This is an example of a SHAPE trial

Key References

Ellefson, M., Shapiro, L., & Chater, N. (2006). Asymmetrical switch costs in children. *Cognitive Development*, *21*, 108-130. DOI: 10.1016/j.cogdev.2006.01.002

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, *124*, 207-231.

Additional Research Summaries

- A precursor to using this sort of task switching with children would have been child versions of the Wisconsin Card Sort Task, Zelazo and colleagues (e.g., Zelazo, Frye and Rapus, 1998) created a modified task for very young children called the DCCS. The standard DCCS provides only one opportunity to switch and doesn't measure the speed of the switch

- Switching in the adult cognitive psychology literature is looks more specifically at accuracy and response times over many trials with predictable and unpredictable switches (e.g., Rogers & Monsell, 1995). These tasks provide a measure of a switch cost – that is the reduction of performance when switching compared to repeating tasks.

- These tasks have been used in a number of studies with children (e.g., Cepeda et al., 2001, Crone et al., 2006; Ellefson et al., 2006; Reimers & Maylor, 2005) and show that switch costs decrease from about 5 years to around 20, hold stable, then increase slowly after 30 years of age.

- The current task was developed by Ellefson et al., 2006 as it is a way of combining the adult task switching literature with the basic rules of the DCCS.

Instruction Slides

Welcome to the Colour-Shape Challenge!

Before you start ...

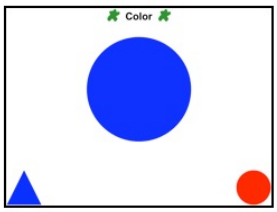
- Make sure that your computer's sound is on.
- Only click or press the button as instructed. (Extra response could crash the site and you will have to begin the game again.)
- Try to finish the entire challenge in one go, as if you leave the site you'll have to start over from the beginning.

Instructions

In this Challenge you are going to match some object by their shape or colour. You will see a circle or triangle in the middle of the screen; it will be red or blue.

Your job is to choose one of the little items at the bottom of the screen that matches that big item as quickly as possible. Sometimes, you are going to choose the item that matches in colour and other times an item that matches in shape.

Let's look at an example for colour.



Colour Example

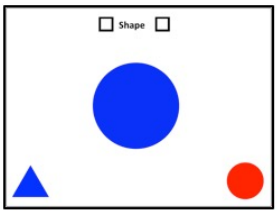
If you see

Color

at the top of the screen, then you should find the small figure that is the SAME COLOR as the big figure.

When looking for the same COLOUR, the **little BLUE triangle** matches the **big BLUE circle**. You will press the arrow key on the same side as the object as quickly as possible. Because you want the **little BLUE triangle** in this example, you would press the arrow key on the left-hand side of the keyboard as quickly as possible.

Next, let's look at an example for shape.



Shape Example

If you see

Shape

at the top of the screen, then should find the small figure that is the SAME SHAPE as the big figure.

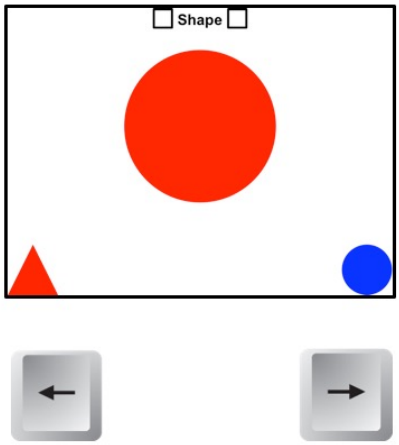
When looking for the same SHAPE, the **little red CIRCLE** matches the **big blue CIRCLE**. Because you want the **little red CIRCLE** in this example, you would press the arrow key on the right-hand side of the keyboard as quickly as possible.

Let's try some for practice

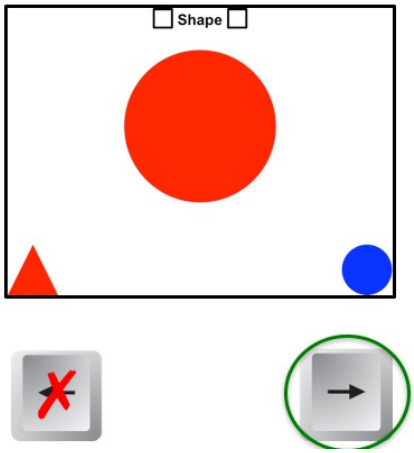
- There are two items for you to try for practice.
- For each one think about whether you would press **the left key or the right key**.
  - DO NOT actually press the key just yet
  - (you get to press the keys when do the real items)

- Once you have decided which key, then press move to the next slide to find out the correct answer.

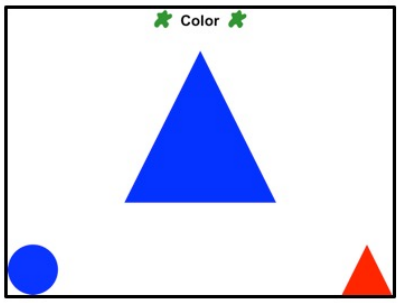
Which key would you choose?

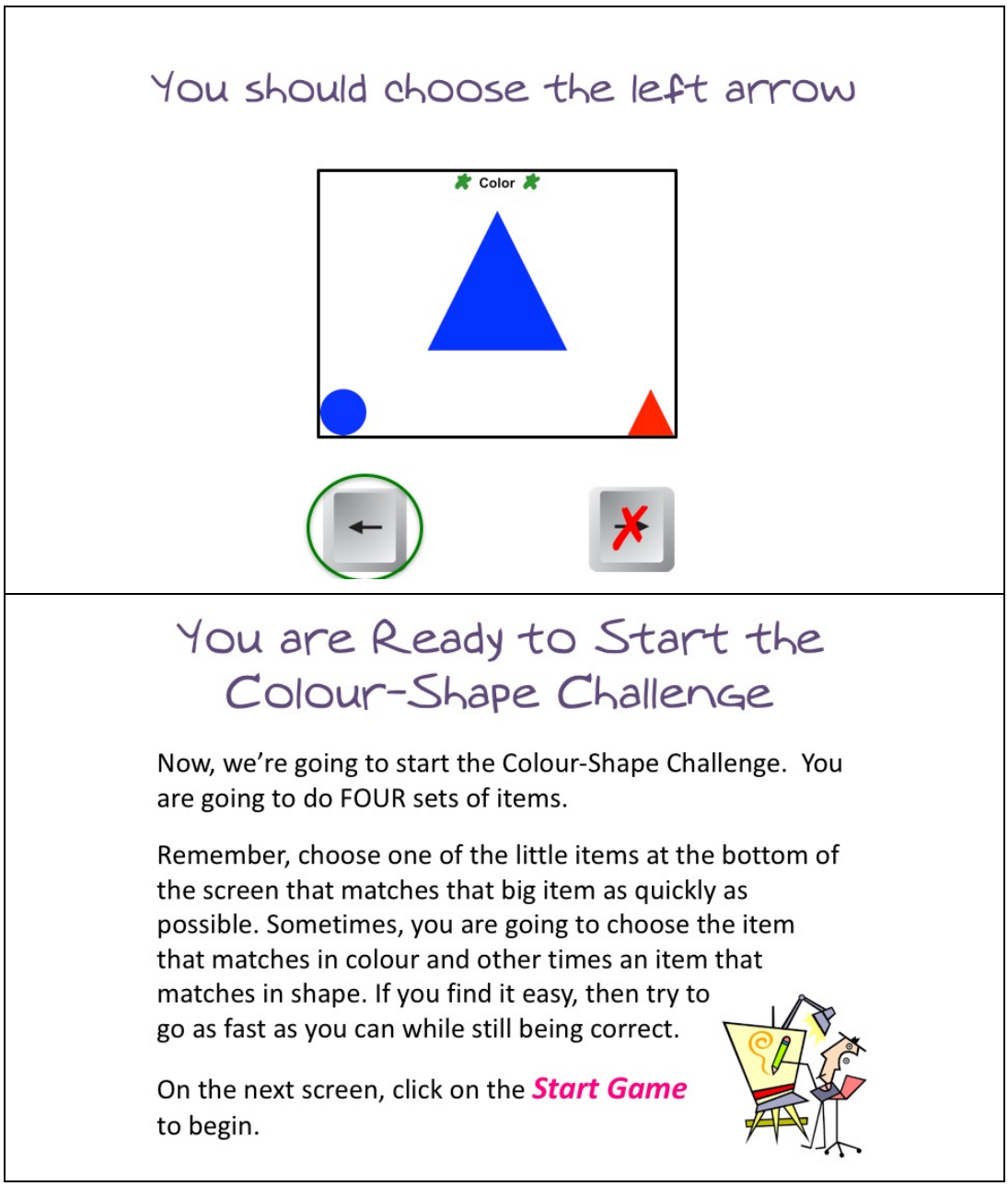


You should choose the right arrow



Which key should you choose?





Experiment Structure

- There are 4 sets randomly presented sets; each set includes of 32 randomly presented items
    - All colour – 32 trials of all colour trials
    - All shape – 32 trials of all shape trials
    - Alternating runs (2 blocks)
        - Colour-Colour-Shape-Shape-Colour-Colour-Shape-Shape (etc.) for 32 trials
        - Shape-Shape-Colour-Colour-Shape-Shape-Colour-Colour (etc.) for 32 trials
- In between sets, participants are given an opportunity to take a break – this can be as long as needed

- Participant responses collected
    - Buttons pressed (left and right buttons are the only ones accepted)
    - RT (in msec) for each button press
    - Accuracy for each trial

Break and Feedback Slides

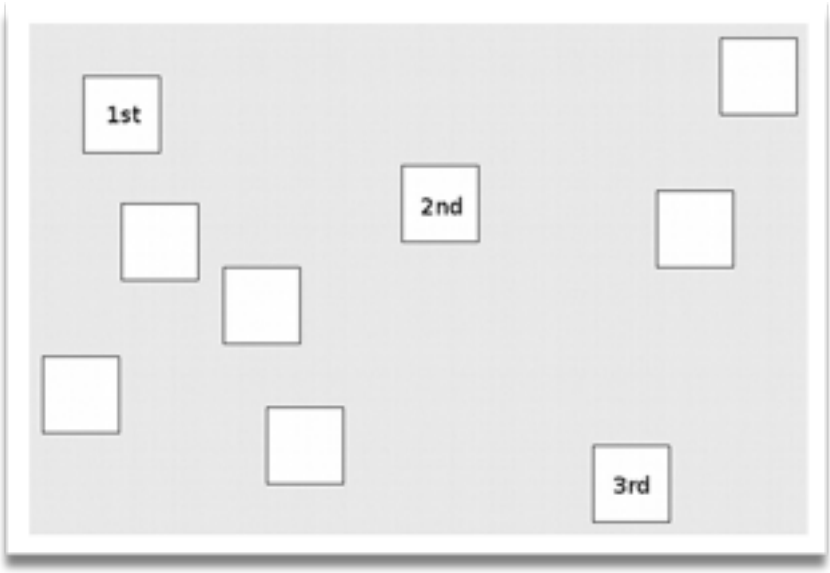
Common Implementation Issues

- The switches are predictable, don't worry there are switch costs with predictable switches
- Participants not engaged with the task could just hit the same button throughout.
- Make sure participants are not resting their fingers on the keys as this may cause the site to crash.
- Participants who complete this task in large groups should finish it at roughly the same time.

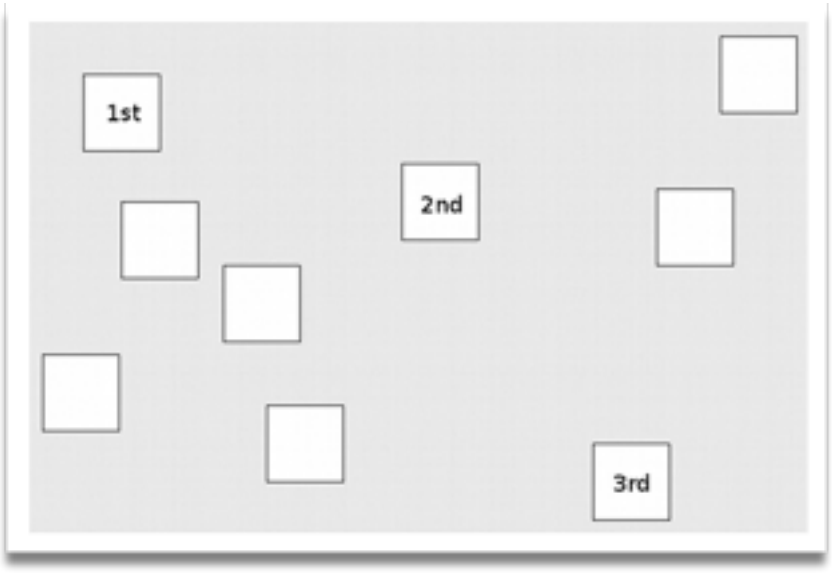
The Patterns Challenge

Overview

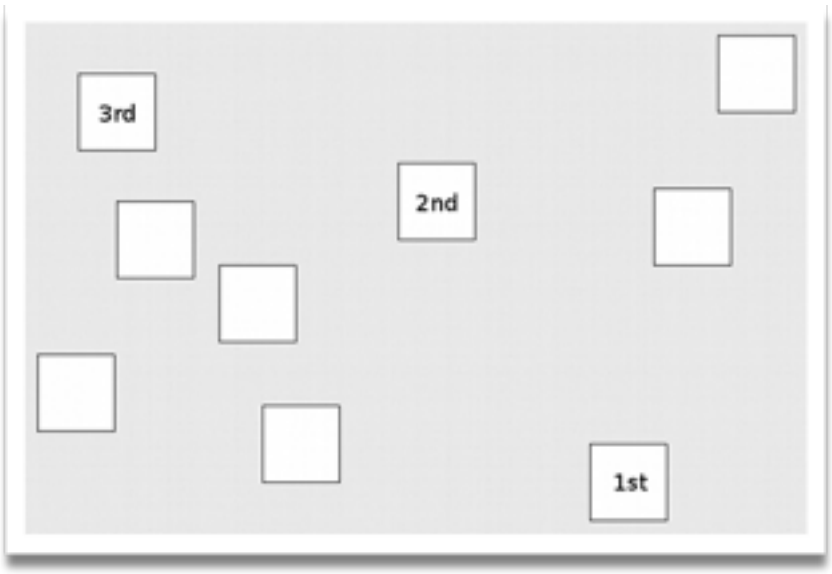
- The patterns challenge is a modification of the corsi block task and is a measure of working memory.
- The aim of this game is to remember the sequences presented on the screen. In each trial the sequences gradually become more difficult with more steps to remember.
    - The participants see nine randomly placed squares that light up one at a time, in a specific order.
    - The participants view a series of boxes that light up one at a time, in a specific order. The participant is required to remember this sequence and click on the boxes in the order they lit up.
- There are two parts of this task
    - Forwards
        - The aim of this game is to remember the sequences presented on the screen and click on the squares in the same order they lit up.
        - In each trial the sequences gradually become longer and more difficult to remember.
    - Backwards
        - The second half of the game requires the participant to click on the boxes in the reverse order that was shown.
- Each part ends when the participant gets five sequences in a row wrong.



Given that the boxes light up in the order above, then



Participants would click on the boxes in the same order as they were lit up for the Forwards Task, but



They would click on the boxes in the opposite / reverse order for the Backwards task

Key References

Corsi, P.M. (1972). *Memory and the medial temporal area of the brain*. Doctoral Thesis: McGill University.

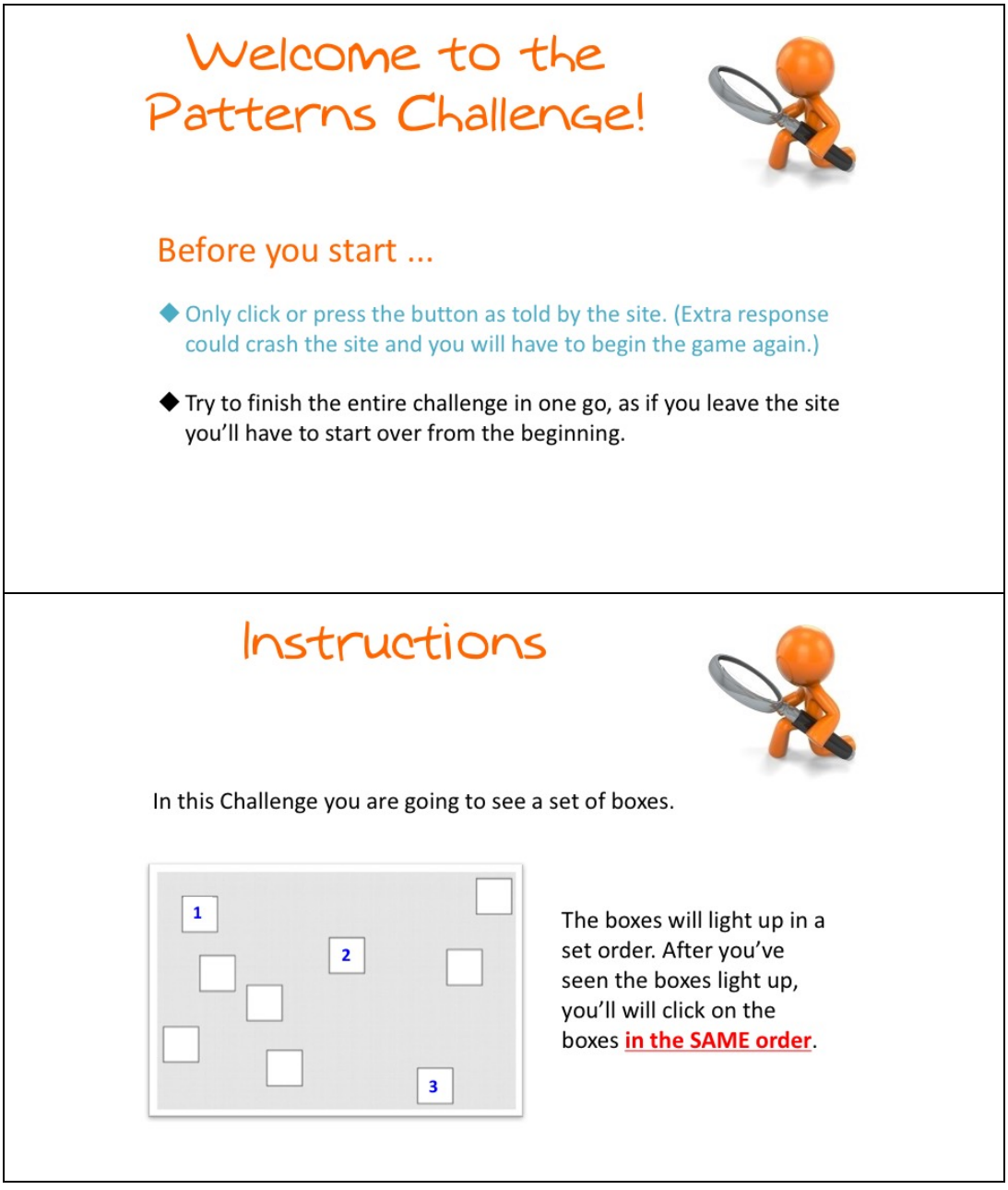
Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin*, *27*, 272-277.

Additional Research Summaries

- Pagulayan et al (2006) used the corsi block task with children aged 7 to 14 years and a group of adults aged 21. No gender differences emerged from the data however performance on the task did improve with age between the ages of 7 and 14. There was no significant difference between the performance of 14 year olds and 21 year old individuals.

- Bull, Espy & Weibe (2008) found that performance on the corsi block task at age 4 predicted mathematics ability at age 7.
- Kessels et al (2000) used the corsi block task with individuals with cerebral lesions and found that right hemisphere patients' performance was poorer than left hemisphere patients. The authors concluded that this task can effectively been used to examine visuospatial memory in brain damage patients.

Instruction Slides



Start the Patterns Challenge

Remember, click on the boxes in the same order that you see them.

If you find it easy, then try to go as fast as you can while still being correct.

On the next screen, click on the ***Start Game*** button to begin.

You have finished the first part of the Patterns Challenge

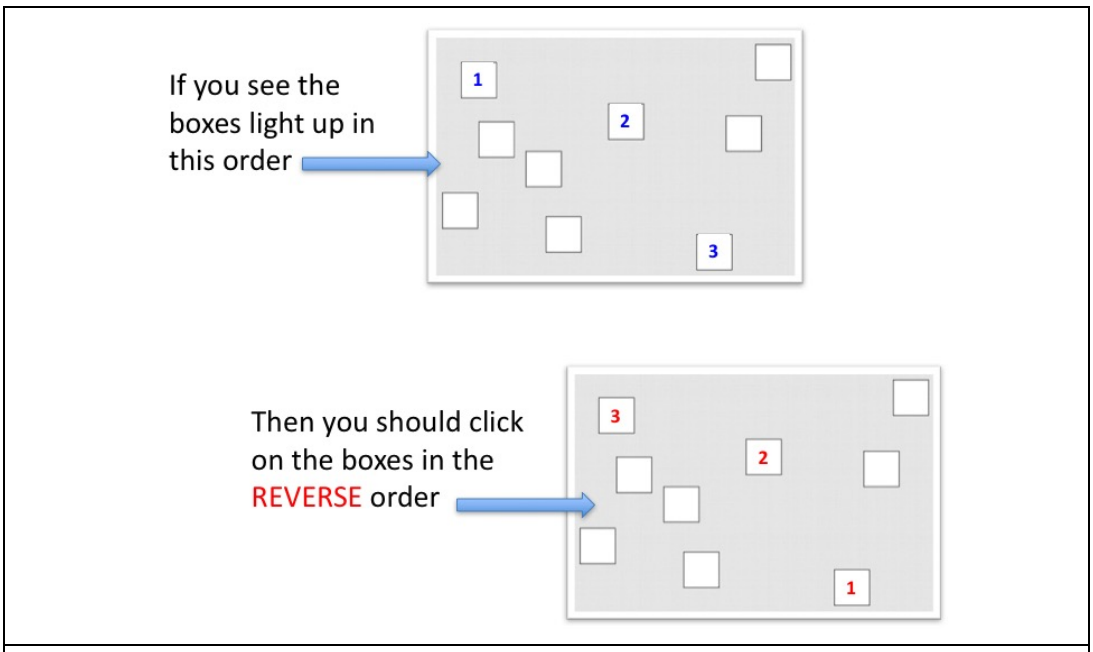
Excellent!

You still have **ONE MORE** part to go …

Now, let's try a different Patterns Challenge

Backwards Challenge Instructions

Just like before you will see boxes light up in a specific order. After you've seen the boxes light up, you'll will click on the boxes **in the REVERSE order**.



Experiment Structure

Forwards Task

- 2 items selected from each length (2, 3, 4, 5, 6, 7, 8, and 9) the British Ability Scale's Forward Digit Span task (identical to the Differential Ability Scale)
- These 16 items are presented sequentially, following the rules for the Forward Digit Span Task
- For each trial –
    - Participants will see a sequence of blocks light up.
    - Participants are prompted to click on the blocks in the same order
    - Once they have finished they press a 'finished' button

- Participant responses collected
    - Which boxes are clicked, and in which order the boxes are clicked
    - Timing for each click (RT, in msec)
    - Timing to complete the sequence (RT, in msec)

Backwards Task

- 2 items selected from each length (2, 3, 4, 5, 6, and 7)the British Ability Scale's Backward Digit Span task (identical to the Differential Ability Scale)
- These 12 items are presented sequentially, following the rules for the Backwards Digit Span Task
- For each trial –
    - Participants will see a sequence of blocks light up.
    - Participants are prompted to click on the blocks in the **reverse** order
    - Once they have finished they press a 'finished' button
- Participant responses collected
    - Which boxes are clicked, and in which order the boxes are clicked
    - Timing for each click (RT, in msec)
    - Timing to complete the sequence (RT, in msec)
    - Accuracy for the sequence

Break and Feedback Slides

Common Implementation Issues

- Some participants will perseverate with the change of rules during the backwards challenge – do not panic, this is part of what is being measured (keeping the new instructions in mind).

- The task stops after five consecutive errors so participants should finish near the top of their ability.

- Participants may vary dramatically on the time taken to complete this task.

The Soccer (Football) Challenge

Overview

- The football challenge is a stop signal task and measures response inhibition.
- The aim of the game is to indicate by pressing on the right and left arrow keys, which direction one would run for the ball.
- In this game the participant views a ball on a pitch. The ball is either on the far right or the far left on the pitch. The aim of the game is to indicate by pressing on the right and left arrow keys, which direction you should run for the ball i.e. press the right arrow if the ball appears on the far right and the left arrow if the ball appears on the far left.
- However, if a whistle sounds NO keys must be pressed until the next ball image appears.
- The correct keys must be pressed as quickly as possible as both accuracy and response times are collected for each response.

For this trial the LEFT arrow would be pressed

For this trial the RIGHT arrow would be pressed

Key Reference

Logan, G. (1994). On the ability to inhibit thought and action: A users' guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189-239). San Diego, CA US: Academic Press.

Additional Research Summaries

- Senderecka et al (2012) compared performance on the stop signal task between children with ADHD and typically developing children (matched on age and gender). Results indicated that typically developing children outperformed children with ADHD who showed significantly impaired inhibitory control.

- This replicates previous work by Dimoska et al (2003) who found that children with ADHD had slower inhibitory process and Lipszyc & Schachar's (2010) meta-analysis who also found deficits in the reaction time of ADHD individuals on the stop signal task. Senderecka et al (2012) concluded that the stop-signal task can effectively differentiate between children with hyperactivity and typically developing children.

- St Clair-Thompson & Gathercole (2006) examined executive functions and academic achievement in children aged 11 and 12. To gain information on children's inhibitory control, they administered the stop signal task. Results revealed that inhibition was linked to achievement in English, Mathematics and Science.

Instruction Slides

Welcome to the Football Challenge!

Before you start ...

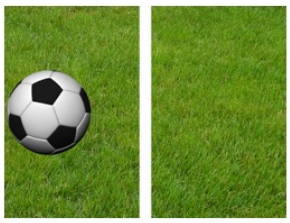
- Make sure that your computer's **sound is on**.
- Only click or press the button as told by the site. (Extra response could crash the site and you will have to begin the game again.)
- Try to finish the entire challenge in one go, as if you leave the site you'll have to start over from the beginning.

Instructions

In this Challenge you are going to see a football. Your job is to indicate which direction to run for the ball as fast as possible without making mistakes.

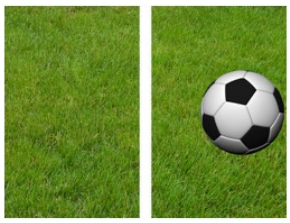
However, sometimes, you are going to hear a referee's whistle. When you hear the whistle, you need to STOP! and not press any buttons until that picture disappears and you move onto the next one.

If the ball is on the LEFT side



then you press the LEFT ARROW key on your keyboard as quickly as possible.

If the ball is on the RIGHT side



then you will press the RIGHT ARROW key on your keyboard as quickly as possible.

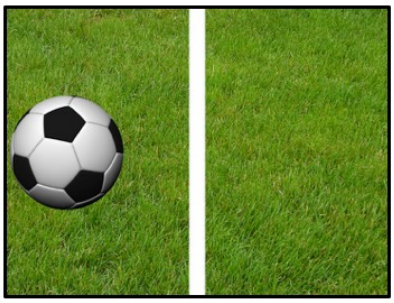
When you hear a referee's whistle you need to **STOP! and not press any buttons until the picture disappears** and you move onto the next one.

Let's try some for practice

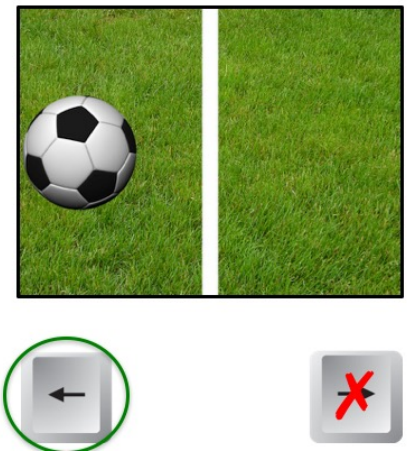
- There are two items for you to try for practice.
- For each one think about whether you would press **the left key, right key, or no keys.**
  - DO NOT actually press the key just yet
  - (you get to press the keys when you do the real items)

- Once you have decided which key, press the green arrow to move to the next slide to find out the correct answer.

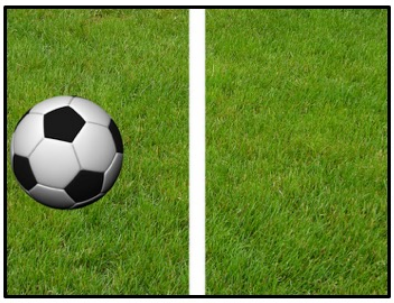
Which key should you choose?



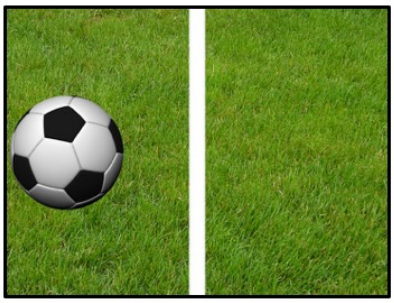
You should choose the left arrow



Which key should you choose?



You heard the whistle - you should NOT choose any key and wait for the next one



Experiment Structure

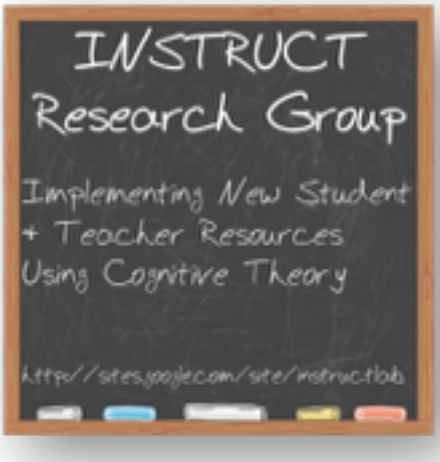
- There are 3 sets of 36 randomly presented items that include equal numbers of stimuli with the ball on the left-hand and right-hand side
    - In between sets, participants are given an opportunity to take a break – this can be as long as needed
- During each set about 6/7 trials are STOP trials (i.e., a whistle blowing)
    - Across the 3 sets, there are a total of 108 trials, with about 20% of those being STOP trials and 80% being GO trials
- Initially, the gap between the picture appearing and the whistle blowing is 250 msec
    - If participant successfully inhibits a response after a whistle blows, then the gap increased by 50 msec for the next STOP trial
    - If the participant does not inhibit a response after a whistle blows, then the gap is decreased by 50 msec for the next STOP trial
- Participant responses collected
    - Buttons pressed (left and right buttons are the only ones accepted)
    - RT (in msec) for each button press
    - Gap (in msec) between the stimulus and the whistle
    - Accuracy for the left/right and for GO/STOP

Breaks and Feedback Slides

Common Implementation Issues

- The gap between the picture and the whistle blowing increases the more accurate the participant is. This can often be frustrating for participants and the researcher needs to be aware of this to reassure the participant.
- This adjustment, means that most participants will get about half of the inhibition trials correct – the important measure is the inhibition gap.
- Participants sometimes press the button too quickly or may rest on keys (without realizing it) and then think that the slide hasn't moved ahead. Do not worry about this as we can remove these trials – just press the button to move the participant to the next trial.
- Make sure participants are not resting their fingers on the keys as this may cause the site to crash.
- Participants who complete this task in large groups should finish it at roughly the same time.

Acknowledgements



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