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# Understanding how people look up and enter information for a data entry task in financial office settings

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*Author:*  
Judith BORGHOUTS

*Supervisors:*  
Dr. Duncan BRUMBY  
Dr. Anna COX

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UCL Interaction Centre,  
Department of Psychology,  
University College London

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## Chapter 4

# Understanding the effect of IAC on looking up information

### Chapter outline

The previous chapter demonstrated that for an expenses task, people have to copy data from multiple sources that differ in terms of their IAC. This chapter describes two studies that explore the extent to which IACs influence strategies, speed and accuracy.

Study 3 tests how IAC affects switching behaviour when copying from one source. It tested whether the effect of IAC on copying colours, as shown in previous studies, extends to copying numbers. Study 4 tests how IAC affects switching behaviour when information for one entry task has to be collected from multiple sources. Together these studies intend to show that IAC affects how people switch between entering and looking up information.

## 4.1 Study 3: Copying numbers from one source

### 4.1.1 Introduction

Study 1 and 2 illustrated that people had to retrieve and copy data from multiple sources with varying information access costs (IAC). People were not always able to look at the data source while entering data, and information sometimes had to be briefly kept in memory before people could enter it. In this situation, people have various options: they can decide to keep going back to the target source, reduce their memory load by writing it down, or keep as much of it in memory. Participants in Study 1 explained they tried to do it in the quickest way possible, and preferred to keep data in memory as this was often a faster strategy than writing it down, printing it out, or going back and forth between the source and the input window.

This is in line with previous lab studies, which showed that as the cost to access information increases, people increasingly rely on the information in their head rather than the information in the environment (e.g. Gray, Sims, Fu, & Schoelles, 2006; Morgan, Patrick, Waldron, King, & Patrick, 2009). People look at the target source longer before copying anything, but after one look, they do enter more items in one sequence before looking back.

Gray & Fu (2004) conducted a study where people had to copy over VCR programming information. Participants either had permanent access to the information, the information was covered by a grey box which could be uncovered by hovering over it with the cursor, or they were explicitly instructed and trained before the trial to memorise the information. The people in the latter condition were more accurate than the other conditions in entering the information. This shows that a deeper encoding of the information in memory makes people more accurate in entering the information.

In later studies that further explored the effect of access costs on use of memory, the Blocks World Task (BWT) was used as a task paradigm, which requires people to copy a 3x3 grid of coloured blocks. In these studies, participants relied more on memory as the cost to access the target window increased. In one study, this memory-based strategy made participants better able to resume after interruptions by copying more blocks before having to revisit the target window (Morgan et al., 2009). Looking at overall task performance overall however, they did make more errors overall and took considerably longer to complete the task. In a later paper, the researchers reflected that the coloured blocks participants had to copy may have been too demanding to memorise (Waldron, Patrick, & Duggan, 2011). This abstract visuo-spatial information did not bear any meaning to the participant, in contrast with the VCR programming information used in Gray & Fu (2004) which is more familiar and easy to memorise. This suggests that the type of information to copy influences the effect that IAC might have on task performance, though the studies differed in task paradigm making it hard to compare their findings: in Gray & Fu (2004) people were explicitly instructed to memorise the information and conducted a test prior to a trial during which they had to fill in the information, and could not continue until they had stated everything correctly. This ensured that people had the information well-memorised before they started the experimental trial. In the Blocks World Task studies, participants were not given this training or instruction.

Rather than training participants to memorise the information, Soboczenski, Cairns, & Cox (2013) used an alternative approach to motivate people to encode the information more deeply. They conducted two studies where people had to transcribe text and numbers that were presented either in a black font colour or a harder-to-read grey font colour. Participants made fewer data transcription errors if data was shown in the harder-to-read font colour, both for transcribing text and numbers. In line with Gray & Fu (2004), these studies showed that when people do make the effort to more deeply encode information in a copying task, it can improve their accuracy.

In order to design data entry interfaces that support how people enter expenses from information sources with varying IACs, it is important to understand how these differences in IAC affect strategy and task performance. Relying on information in the head over information in the world can make it more likely for people to make errors in a copying task (Morgan et al., 2009), though other studies have shown that a deeper encoding of information can also improve accuracy if memorised well (Gray & Fu, 2004; Soboczenski et al., 2013).

The study reported in this chapter replicates the BWT study, by using both coloured and numbered blocks. The purpose of this study is to see whether the effect on IAC on people's strategies and performance, as reported in previous BWT studies, holds when people have to copy numbers instead of colours.

It is expected that the effect of IAC on strategy will be similar and that an increase in IAC will encourage people to adopt a more memory-based strategy. However, the expectation is that numbers are easier to memorise and people will be able to memorise more items. Furthermore, based on previous findings that a deeper encoding of numbers in memory can reduce errors, it is expected that an increased IAC will improve accuracy for copying numbers.

## 4.1.2 Method

### Participants

Forty-two participants (eight male) were recruited from the UCL Psychology Subject Pool. Ages ranged from 18 to 52 with a mean age of 22.38 ( $SD = 7.45$ ). Participants received course credit or £3.75 as a compensation for taking part in the study.

### Design

A mixed design was used with two independent variables: IAC and block type. The between-participants variable was the level of IAC which had three levels. If the IAC was Low, the target pattern was permanently visible. In the Medium and High IAC conditions, the target pattern was covered with a grey mask, and could only be uncovered by moving the mouse cursor over the window. The mask reappeared as soon as the cursor left the window. In the High IAC condition, there was an additional 1-second delay to uncover the mask. This delay time was used in previous BWT studies where it showed to have a significant effect on task strategies and performance (Gray et al., 2006; Morgan et al., 2009; Waldron, 2007). The within-participants variable was the block type to be copied, which was either coloured or numbered blocks. The order was counter-balanced across participants.

The dependent variables are listed in Table 4.1. The primary focus is on the measures of the first visit, as participants do not have any information yet on the target pattern. On subsequent visits, they may already have partial information in their head from previous visits. Therefore, the items copied after the first visit is believed to be the most 'sensitive measure of performance' (Janssen & Gray, 2012). Two dependent variables were used to measure accuracy. Incorrectly placed blocks measured instances where a participant initially placed a block in the incorrect place, but then moved this to the correct place prior to submitting the pattern. Incorrectly submitted trials measured instances where the participant had finished copying a pattern and clicked the Submit button, but the pattern was incorrect.

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#### Strategy measures

Number of visits to target window

Visit duration of first visit (s)

Average duration of visits (s)

Number of blocks copied after first visit

Number of blocks copied correctly after first visit

#### Global task performance measures

Number of incorrectly placed blocks (per trial)

Number of incorrectly submitted trials (per experiment block)

Trial completion time incl. and excl. lockout (s)

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**Table 4.1:** Dependent variables used in the study.



Trial: 1/15  
Please copy the pattern on the left into the window on the right, using the blocks at the bottom of the screen.

3	4	7
5	9	6
1	8	2


Submit

Resource Window

(a) The number condition.

Please copy the pattern on the left into the window on the right, using the blocks at the bottom of the screen.



Submit


(b) The colour condition.

**Figure 4.1:** The task lay-out with the three different components.

## Materials

Figure 4.1 shows the task paradigm that was used. Each colour or number was only used once. The colours used were similar to the colours used in previous BWT studies (e.g. Gray et al., 2006; Morgan et al., 2009). Participants had to copy and complete fifteen patterns of each block type, and each participant had to copy over the same patterns. The target window showed a 3x3 grid with either coloured or numbered blocks. The output window showed an empty 3x3 grid, and was the same size as the target window. Participants had to copy the pattern shown in the target window by dragging blocks from the resource window and moving them into the output window.

The study was conducted on a desktop computer, using a 24-inch monitor with a resolution of 2048 x 1152 pixels. Participants used a computer mouse to drag and drop blocks. The experimental task was implemented using HTML, Javascript and PHP and run in a browser. All relevant browser events, such as mouse movements to (un)cover the grey mask, dragging and dropping the blocks and mouse clicks, were recorded and saved in a MySQL database. The browser window covered the whole screen to minimise distractions.

For the Low IAC condition, eye fixations were used to measure the number and duration of visits to the target window. Eyetracking data was also obtained for the Medium and High IAC conditions. However, this data was not used due to the fact that people were able to also view the target window area whilst the target pattern was covered. Therefore, in accordance with previous IAC studies (e.g. Gray & Fu, 2004), for the Medium and High IAC conditions the number and duration of uncovering the mask was taken as a measurement for visits to the target window. These uncoverings were measured by Javascript. The usefulness and limitations of using these measures are discussed in the Discussion.

A Tobii T60 eyetracker was used for recording people's eye fixations. Eye movements were recorded at a rate of 60 gaze data points per second for each eye, with an accuracy of 0.5 degrees and timestamp accuracy of 4 ms. For the analysis, all consecutive eye fixations with no drag or drop actions in-between were added together and counted as one fixation.

## Procedure

Participants were welcomed and briefed about the experiment. It was explained they would be shown nine blocks which were in a certain order, and had to copy this order by moving blocks around. Participants were instructed to complete the task as fast as possible, but it was explained that they were not able to continue until they had copied a pattern correctly. The experiment was broken down in two parts, one where they had to copy colours, and one where they had to copy numbers. For each part, they were given two practice trials first to get familiar with the set-up, and to give them a chance to ask questions if anything was unclear. There was an opportunity for the participant to take a break between the two parts. They were then asked to read and sign a consent form and given an information sheet with a summary of the study and the researcher's contact details. In addition to the verbal briefing, the explanation of the study was written out on the computer screen for the participant to read and they were shown an instruction video that showed how the experiment worked. The study took around 20-30 minutes to complete.

## Ethical considerations

The study was undertaken with ethical approval from the UCL Research Ethics Committee [Project ID Number UCLIC/1415/001/Staff Brumby/Borghouts]. At the start of each study, participants were first briefed verbally about the study. They were asked to read and sign a consent form, and were given an information sheet to keep. This information sheet contained

a summary of the study information and the researchers' contact details. It was explained that an eyetracker would record their eye fixations and movements, but that these recordings were anonymous and that they would not be directly identifiable. After participants had completed the first part of the experiment, a prompt appeared on the screen advising them to take a short break. Participants could take a break as long as they wanted and could decide themselves when to continue with the second part of the experiment.

Participants were informed that the data would be used for research purposes only and stored in accordance with the Data Protection Act 1998. They were also informed that their data would be anonymised and when used in a report or academic paper, their data would not be directly identifiable.

### 4.1.3 Results

The means and standard deviations of all dependent variables are shown in Table 4.2.

Eight participants were removed from the analysis due to weak eye-tracking calibration. Furthermore, one participant misunderstood the experiment and did not know she was allowed to uncover the mask of the target window more than once. This participant had scores that were more than three times the interquartile range from the rest of the participants' scores on six different variables, so this participant was considered an outlier and removed from the analysis.

#### Task strategies

##### Number of visits to the target window

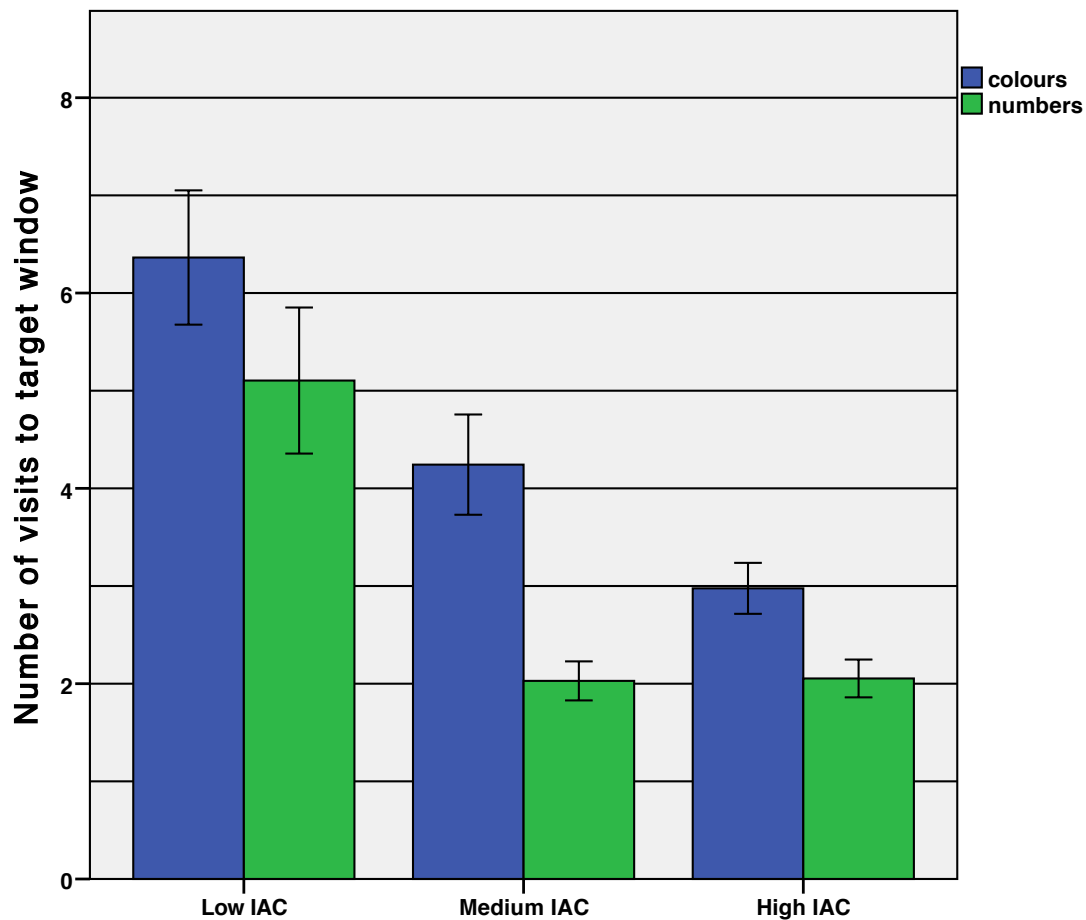
Participants made fewer visits to the target source when they had to copy numbers ( $M = 3.06$ ,  $SD = 2.08$ ) than when they had to copy colours ( $M = 4.49$ ,  $SD = 2.18$ ),  $F(1,30) = 41.62$ ,  $p < .001$ ,  $\eta^2 = 0.58$ . Participants also made fewer visits as IAC increased from Low ( $M = 5.73$ ,  $SD = 2.41$ ), to Med ( $M = 3.13$ ,  $SD = 1.65$ ), to High ( $M = 2.51$ ,  $SD = 0.91$ ),  $F(2,30) = 15.16$ ,  $p < 0.001$ ,  $\eta^2 = 0.50$ . To investigate differences between conditions, post-hoc Tukey comparisons were performed. Results showed that participants made significantly fewer visits in the Medium-IAC condition than in the Low-IAC condition,  $p < .01$ . However, there was no difference in number of visits between the Medium-IAC and the High-IAC conditions,  $p = .59$ . Participants looked at the target window for colours more on every level of IAC (see Figure 4.2), and so there was no significant interaction,  $F(2,30) = 2.82$ ,  $p = .08$ ,  $\eta^2 = 0.16$ .

##### Duration of first visit to target window

There was no significant main effect of block type on the duration of the first visit,  $F(1,30) = 3.05$ ,  $p = .09$ ,  $\eta^2 = 0.09$ . Participants looked longer at the target source as IAC increased from Low to High. Post-hoc comparisons showed that participants looked longer in the High-IAC condition ( $M = 1.84$ ,  $SD = 1.35$ ) than in the Low/Medium-IAC conditions,  $ps < .001$ . However, there was no difference in duration between the Low-IAC ( $M = 0.45$ ,  $SD = 0.46$ ) and the Medium-IAC ( $M = 0.05$ ,  $SD = 0.04$ ) conditions,  $p = .47$ . There was a significant interaction effect between IAC and block type,  $F(2,30) = 5.70$ ,  $p < .01$ ,  $\eta^2 = 0.28$  (see Figure 4.3). There were no difference between block types in the Low-IAC condition,  $t(10) = -1.86$ ,  $p = 0.09$ , nor the Medium-IAC condition,  $t(9) = -0.29$ ,  $p = 0.7$ . However, in the High-IAC condition, participants looked significantly longer for colours ( $M = 2.18$ ,  $SD = 1.59$ ) than numbers ( $M = 1.49$ ,  $SD = 1.01$ ),  $t(11) = 2.76$ ,  $p = 0.02$ .

1.3						
	Colours			Numbers		
	Low	Medium	High	Low	Medium	High
<b>Strategy measures</b>						
Number of visits to target window	<b>6.36</b>	<b>4.24</b>	<b>2.98</b>	<b>5.10</b>	<b>2.03</b>	<b>2.05</b>
	2.28	1.62	0.90	2.48	0.63	0.67
Visit time of first visit (s)	<b>0.39</b>	<b>0.04</b>	<b>2.18</b>	<b>0.51</b>	<b>0.04</b>	<b>1.49</b>
	0.23	0.02	1.59	0.45	0.05	1.01
Average time of visits (s)	<b>0.29</b>	<b>0.04</b>	<b>1.54</b>	<b>0.35</b>	<b>0.04</b>	<b>1.07</b>
	0.13	0.02	0.95	0.15	0.03	0.77
Number of blocks copied	<b>1.90</b>	<b>3.55</b>	<b>4.52</b>	<b>2.44</b>	<b>6.18</b>	<b>6.33</b>
after first visit	1.84	1.93	1.43	1.89	1.61	1.67
Number of blocks copied correctly	<b>1.86</b>	<b>3.22</b>	<b>4.07</b>	<b>2.36</b>	<b>5.96</b>	<b>5.98</b>
after first visit	1.75	1.83	1.20	1.74	1.52	1.55
<b>Global task performance measures</b>						
Number of incorrectly placed blocks	<b>0.15</b>	<b>0.67</b>	<b>0.79</b>	<b>0.17</b>	<b>0.31</b>	<b>0.46</b>
(per trial)	0.18	0.40	0.44	0.19	0.18	0.16
Number of incorrectly submitted	<b>0.27</b>	<b>1.9</b>	<b>2</b>	<b>0.36</b>	<b>0.5</b>	<b>0.83</b>
trials (per experiment block)	0.65	2.51	2.13	1.21	1.08	1.03
Trial completion time incl. lockout	<b>19.60</b>	<b>25.40</b>	<b>31.80</b>	<b>19.47</b>	<b>20.83</b>	<b>25.95</b>
(s)	2.98	5.16	6.08	3.03	3.08	4.21
Trial completion time excl. lockout	<b>19.60</b>	<b>25.40</b>	<b>28.84</b>	<b>19.47</b>	<b>20.83</b>	<b>23.89</b>
(s)	2.98	5.16	6.34	3.03	3.08	4.06

**Table 4.2:** The effect of IAC on copying colours and numbers. The means are shown in bold, the standard deviations are below the means.



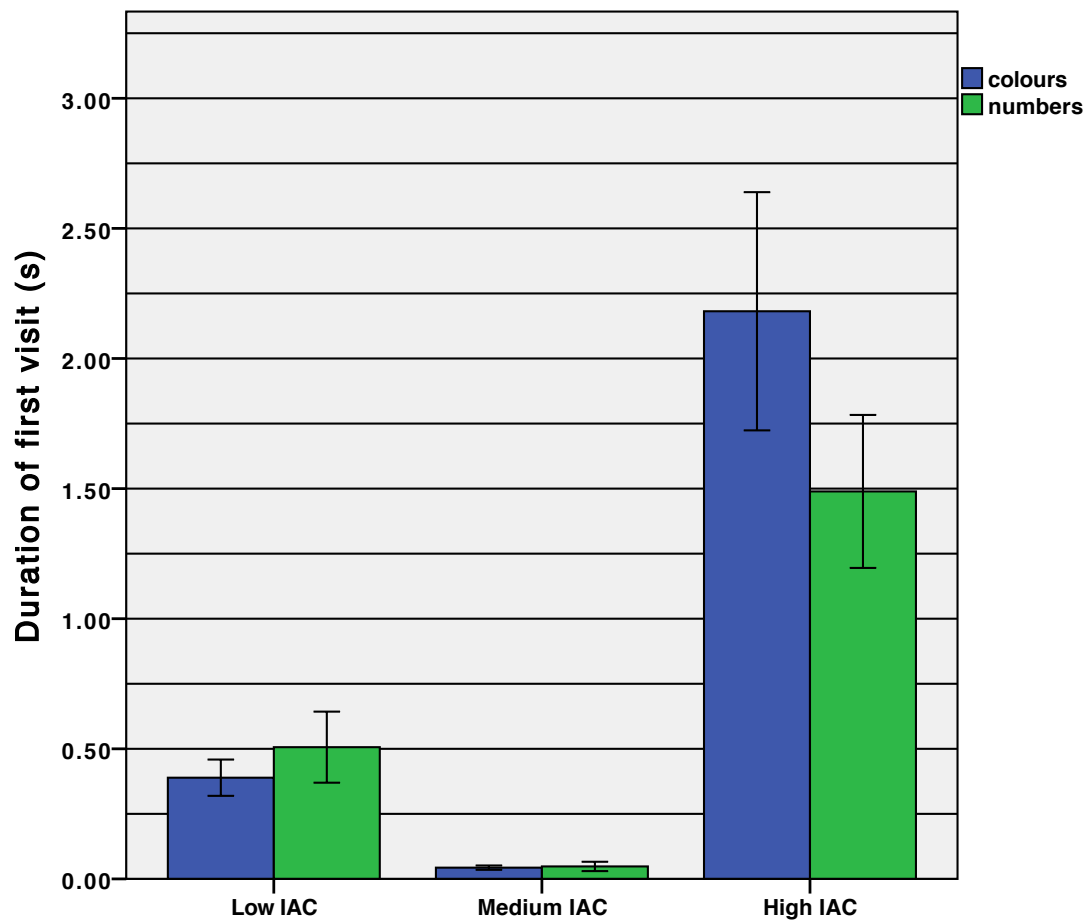
**Figure 4.2:** The interaction between block type and IAC for number of visits to the target window. The error bars represent  $\pm 1$  standard error.

### Blocks placed after first visit

People placed more blocks correctly after the first visit for numbers ( $M = 4.77$ ,  $SD = 2.33$ ) than colours ( $M = 3.08$ ,  $SD = 1.81$ ),  $F(1,30) = 63.86$ ,  $p < .001$ ,  $\eta^2 = 0.68$ . They also placed more blocks as IAC increased,  $F(2,30) = 12.54$ ,  $p < .001$ ,  $\eta^2 = 0.46$ . Tukey post-hoc comparisons show there was a difference between the Low IAC and Medium/High IAC conditions ( $ps < .01$ ), but not between Medium and High IAC conditions ( $p = .77$ ). There was a significant interaction effect between IAC and block type,  $F(2,30) = 8.96$ ,  $p < .01$ ,  $\eta^2 = 0.37$  (see Figure 4.4). When IAC was Low, the number of blocks that were copied correctly after the first visit did not differ significantly for colours or numbers.

### Global task performance

The interactions between block type and IAC on global task performance measures all had the same trend: people performed the same for colours and numbers when IAC was Low, but differences appeared between the block types as IAC increased. As this trend was the same for each interaction, the statistical results of the interactions are reported but their specific trend will not be repeated.



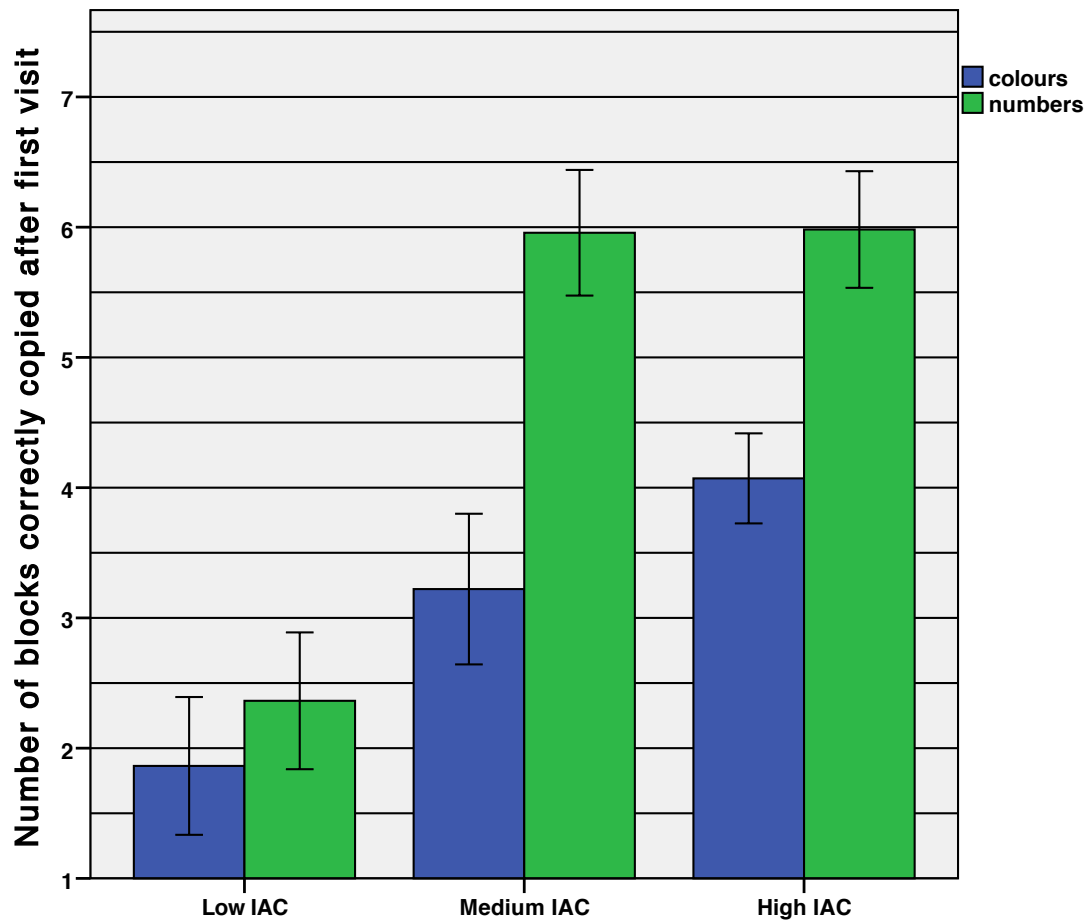
**Figure 4.3:** The effect of IAC on the duration of the first visit to the target window. The error bars represent  $\pm 1$  standard error.

#### Number of incorrectly placed blocks

Participants placed more blocks incorrectly for colours ( $M = 0.54$ ,  $SD = 0.45$ ) than numbers ( $M = 0.32$ ,  $SD = 0.21$ ),  $F(1,30) = 10.71$ ,  $p = .003$ ,  $\eta^2 = 0.26$ . As IAC increased and participants were keeping more items in memory, they increasingly placed more incorrect blocks,  $F(2,30) = 14.71$ ,  $p < .001$ ,  $\eta^2 = 0.50$ . Tukey post-hoc comparisons show there was a difference between the Low IAC condition ( $M = 0.16$ ,  $SD = 0.18$ ) and Medium/High IAC conditions ( $ps < .01$ ), but not between the Medium ( $M = 0.49$ ,  $SD = 0.35$ ) and High IAC conditions ( $M = 0.63$ ,  $SD = 0.36$ ) ( $p = .3$ ). There was a significant interaction effect between IAC and block type,  $F(2,30) = 3.36$ ,  $p < .05$ ,  $\eta^2 = 0.18$ . When IAC was Low, the number of blocks that were copied incorrectly did not differ significantly for colours or numbers, but as IAC increased, participants placed more blocks incorrectly for colours.

#### Number of incorrectly submitted trials

The number of trials that were submitted incorrectly was generally low, but participants submitted more incorrect trials for colours ( $M = 0.1$ ,  $SD = 0.16$ ) than numbers ( $M = 0.04$ ,  $SD = 0.08$ ),  $F(1,30) = 5.28$ ,  $p = .029$ ,  $\eta^2 = 0.15$ . There was no significant effect of IAC,  $F(2,30) = 2.70$ ,  $p = 0.08$ ,  $\eta^2 = 0.15$ , nor any interaction,  $F(2,30) = 1.65$ ,  $p = .2$ ,  $\eta^2 = 0.10$ .



**Figure 4.4:** The interaction between block type and IAC for number of blocks correctly placed after the first visit to the target window. The error bars represent  $\pm 1$  standard error.

### Trial time

Two trial completion times are considered here: total time and time excluding lockout. Looking at the actual completion time, participants took longer to complete a trial when they were copying colours ( $M = 25.80$ ,  $SD = 7.06$ ) compared to when copying numbers ( $M = 22.24$ ,  $SD = 4.47$ ),  $F(1,30) = 44.08$ ,  $p < .001$ ,  $\eta^2 = 0.60$ . As IAC increased from Low to Medium to High, participants took longer to complete a trial, IAC,  $F(2,30) = 15.91$ ,  $p < .001$ ,  $\eta^2 = 0.52$ . Tukey post-hoc comparisons show there was a difference between Low/Medium and High ( $ps < .01$ ), but not between Low and Medium ( $p = .12$ ). There was a significant interaction effect between IAC and block type,  $F(2,30) = 11.05$ ,  $p < .001$ ,  $\eta^2 = 0.42$ .

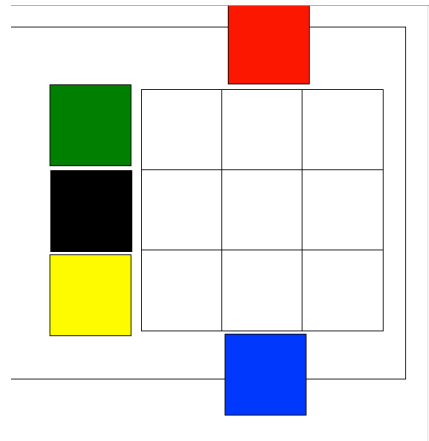
With the lockout time in the High-IAC condition removed, the same effects were found for block type,  $F(1,30) = 34.55$ ,  $p < .001$ ,  $\eta^2 = 0.54$ , and IAC,  $F(2,30) = 8.18$ ,  $p = 0.001$ ,  $\eta^2 = 0.35$ . Tukey post-hoc comparisons show there was still a difference between Low and High ( $p = .001$ ), but no longer between the Medium IAC and Low IAC or High IAC conditions ( $ps > .1$ ). There was a significant interaction effect between IAC and block type,  $F(2,30) = 8.13$ ,  $p = .002$ ,  $\eta^2 = 0.35$ .

### Qualitative data

The screen recordings from the eye-tracker were played back to further investigate people's behaviour. Although this helped understand some behaviour which could not be determined

from the quantitative data alone, these observations only serve to explain some of the quantitative measures and are not the main focus of the analysis.

The visit durations in the Medium IAC condition were suspiciously short. Upon replaying the screen recordings, it appeared that participants often accidentally moved their cursor over the grey mask of the target source. This was counted as a visit by the program, even though participants may have not intentionally moved their cursor to this part of the screen to look at the target source. They did not spend a long time looking at the target window, but also did not immediately move blocks either, and sometimes waited multiple seconds before they made a move.



**Figure 4.5:** Participants placed blocks outside of the output window as 'placeholders'.

During the 1-s lockout in the High IAC condition, participants changed their minds about visiting the target window on numerous occasions. They placed their mouse cursor on the mask, but left this field before it was uncovered to move one or more blocks. It could be this decision also occurred in the Medium IAC condition, but as there was no lockout the mask was already uncovered before people made this decision, and would explain the very short visits.

People sometimes placed the blocks as 'placeholders' as shown in Figure 4.5: they placed several blocks outside of the output window next to the position they thought it belonged to, but did not place it there yet. Only after viewing the target again, they placed the blocks in the output window. Looking at quantitative data alone, this type of strategy would be depicted as one long view at the target, after which all blocks were placed in one go. This is true to some extent, but as people could already place the blocks and offload their memory without this being recorded by the program, they only had to check if this position was correct on the subsequent visit, and is different from a strategy where people spent a long time trying to memorise the blocks after which all blocks were placed.



#### 4.1.4 Discussion

This study replicated the Blocks World Task with the aim to see if the effect on IAC on a copying task, as previously found when using colours, can be extended to copying numbers, and if a deeper encoding of numbers into memory makes people more accurate.

The main findings are:

- Numbers are easier to copy than colours, but only if IAC is increased
- Increases in IAC make people adopt memory-intensive strategies
- Increases in IAC increases errors

#### The effect of block type on task strategies and performance

Changing the block type from colours to numbers made it easier to memorise the blocks: people made shorter and fewer visits than when copying colours, but were still able to place more blocks. This difference in performance is only found in the Medium and High IAC conditions, which further suggests the difference between numbers and colours is due to the memorability of the information, and the interactions on most of the dependent variables further show that the difference between block types was dependent on the level of IAC.

The difference between numbers and colours fit well with the distinction in Baddeley's (1986) seminal model of working memory between processing visuo-spatial and verbal information. As numbers can be rehearsed and therefore refreshed in working memory, they are likely easier to memorise. After the study had ended, several participants in this study explained they used some sort of rehearsal and tried to say the numbers out loud in their head. For colours, some indicated they tried to either capture a mental picture of the colours in their mind, while others rehearsed the word for each colour (e.g. 'red' and 'blue') but they felt they were able to remember fewer items using this strategy. This is consistent with Chincotta, Underwood, Ghani, Papadopoulou, & Wresinski (1999)'s finding that people have a greater memory span for Arabic numerals (e.g. 1, 2, 3) than corresponding words (e.g. one, two, three).

Though an increase in IAC made people rely on memory and people seemed to memorise numbers more easily than colours, an increase in IAC did not make people more accurate in copying numbers as in Gray & Fu (2004), where people had to memorise VCR programming information. The error rate for numbers was however already quite low in all conditions, and moreover people were not explicitly instructed or trained to memorise the information before each trial as in Gray & Fu (2004).

#### The effect of IAC on task strategies and performance

The effect of IAC on people's cognitive strategies, as found in previous studies, is replicated in this study: as the cost of accessing the target window increased, people increasingly relied on memory (Gray et al., 2006; Morgan et al., 2009; Waldron, 2007). People switched from a perceptual to a memory-based strategy by making fewer but longer visits to the target window and placing more blocks immediately after the first visit. This strategy worsened their global performance as they took longer to complete the task and placed more incorrect blocks throughout the trials.

An increase in IAC also made people rely more on memory when copying numbers. When a mask was added over the target window, people visited the target window less often and they placed more blocks after the first visit. In both the Medium IAC and High IAC conditions, people on average placed around six blocks correctly after the first visit, after which they needed

one more visit to look at the last three blocks. The average number of items people can memorise is  $7 \pm 2$  items (Miller, 1956), and potentially six blocks was the maximum that people could reasonably memorise.

In previous studies, adopting a memory-based strategy when copying text and numbers improved accuracy (Gray & Fu, 2004; Soboczenski et al., 2013). In the current study, the hypothesis that memorising numbers due to an increased IAC would make people more accurate is not supported. The error rate was overall low and upon reflection the interaction of moving blocks may have made people sufficiently slow to hardly make any errors. In Gray & Fu (2004) and Soboczenski et al. (2013), people typed in data using a computer keyboard.

With the BWT, it was difficult to measure visits to the target window in the same manner for all conditions. For the Low IAC conditions, eye fixations were used, whereas for the Medium and High IAC conditions, uncoverings of the mask were used. This introduced several problems. First, while eye-tracking measures show how long and how often people are looking at a particular part of the screen, it can not reveal if people are actually perceiving or processing the data that is displayed (Waldron, 2007). For the Medium and High IAC conditions, an interaction was required and a conscious decision had to be made to reveal the target in these conditions. It would therefore seem likely that uncoverings more reliably measure visits to the target window. However, the uncoverings for the Medium IAC conditions were suspiciously short. Playing back the screen recordings suggests participants often accidentally uncovered the window, and it is therefore less clear if these are a reliable measure of actual visits.

## Summary

The purpose of this study was to study the effect of IAC on strategy, speed and accuracy when copying from one source, and investigate if the effect of IAC, as found in previous experimental studies, would extend to copying numbers. In order to be able to compare results of this study with previous IAC studies the same task paradigm of the Blocks World Task was used.

The hypothesis that people would need fewer switches and would perform better for numbers than colours is supported, indicating that numbers are easier to memorise. The hypothesis that memorising numbers due to an increased IAC would make people perform better is not supported. The error rate was overall low and upon reflection the interaction of moving blocks may have made people sufficiently slow to hardly make any errors. Furthermore, in Study 1 people saved up data to enter a lot in one sequence, and errors increase as people have to copy more (Healy, Kole, Buck-Gengle, & Bourne, 2004). Potentially the setup of this experiment was not suitable to reliably measure an increase in errors.

The information was copied from one source, and for each participant the IAC was the same throughout the experiment: it was either low, medium, or high. Therefore, while using the BWT task paradigm was appropriate in comparing its results with previous IAC studies, it did not resemble the data entry tasks observed in the financial office setting of Study 1.

Considering these limitations, it was decided after this study to not continue with the same task paradigm, but certain learning points can be taken away from this study.

First, the entry method matters. An entry method that is sufficiently slow may make people accurate, regardless of the level of IAC. Second, the effect of IAC generalises, but it is not clear how the results of this experimental paradigm can be translated in suggestions in how people dealing with differing levels of IAC can best be supported in their work. In contrast to this study, where information came from one source, and always had the same level of IAC for each participant, Study 1 showed that for entering expenses, people have to enter different types of information, these do not all come from the same source, and each source can have a different access cost.

Third, the measured short visits in the Medium IAC conditions may have confounded the results. In future studies, the setup of the experiment should be designed so that participants do not accidentally access the source when they do not intend to.

Lastly, for each dependent variable, the same consistent measure should be used to compare across conditions. This could be data provided by an eyetracker, or interaction measures such as mouse clicks, key presses or interkey intervals.

The next study will try to more closely simulate the expenses task observed in the financial office setting of Study 1 and 2. People will have to enter and collect information from multiple sources with different IACs. The aim is to see how these differences in IAC influence people's switching strategies between entering and looking up data when copying from multiple sources.

## 4.2 Study 4: Copying data from multiple sources

### 4.2.1 Introduction

Study 3 showed the effect of IAC on people's visiting strategies when copying from a single source. The longer it took to access a source, the more time people spent looking at that source to memorise as much information, and minimise the number of revisits. Though people were able to copy over more items after one visit using this strategy, they also made more errors overall.

In the setting of Study 3, all information was to be found in the same location. People may have tried to memorise too much information per visit, and upon entry relied on incorrectly memorised information in the head. For data entry work in office workplaces, information can be spread over various sources that are not all equally easy or hard to retrieve. How do people prioritise how they enter and look up information from these different sources? And do different strategies have an effect on how fast and accurate they are completing the task?

In the office setting of Study 2, prior to starting data entry participants collected physical sources that were needed and placed them on their desk. They then entered this information, which was nearby, first. They postponed accessing other sources until they needed to enter it during the task. If information took too long to access, they would set aside the task and continue with other tasks. One of the factors that influenced the different strategies appeared to be the expected time cost to retrieve the information.

This study tests the assumption that observed strategies are influenced by the time costs to access information sources. Whilst prior studies described that tasks can involve multiple sources (Cangiano & Hollan, 2009; Su, Brdiczka, & Begole, 2013), there is limited research on how people use these sources, and to what extent the time cost to access a source influences these decisions.

It is expected people will develop strategies as they have to enter data over an extended period of time. For example, they may initially look up each data item the moment they need it, but as they become familiar with the IAC of sources, they may first finish entering all information from low IAC sources, before looking up information of high IAC sources.

**SO WHAT** The identified behaviour of how people manage looking up information is used to create a set of design recommendations for the current expenses system, which are evaluated in Study 5 and 6.

The following questions will be addressed:

1. *How does IAC affect the number of visits to look up information from multiple sources with different IACs?*
2. *How does IAC affect the sequence/order of visits to look up information from multiple sources with different IACs?*

3. *Do the number and sequence of visits affect data entry accuracy and speed?*

## 4.2.2 Method

### Participants

Thirty-three participants (12 male) with a mean age of 26 years ( $SD = 8$ ) took part in the experiment. They were recruited from a university subject pool and received £4 for their participation.

### Task

The experimental data entry task was framed around an expenses task as observed in Study 1 and Study 2. In an original expenses task, the user has to complete a number of data entries regarding incurred expenses in order to claim back the money, such as the expense made, the reason for making the expense, the date of the expense, and the account on which to claim back the money. They fill this into a claim form, which looks similar to a spreadsheet.

Because the focus of this study was on the time cost to retrieve the data to be entered, and not on different type of data items per se, the participants only had to fill in two type of data items. In the current study, participants had to fill in a financial amount to specify the expense that was made, such as £11.49, and an account code to determine from which account to claim back the expense, such as 654273. Participants had to enter two expenses per trial, and thus had to enter two amounts and two account codes.

The experimental task can be viewed in Figure ?? . Participants had to switch between five computer windows on the computer screen. One window contained the data entry form, in which the data had to be entered. The two financial amounts and two account codes had to be retrieved from the other four windows, and entered in the corresponding fields on the data entry form. A window was revealed by clicking on the corresponding name in the horizontal menu, at the top of the screen. The names of computer windows with an increased IAC were underlined, to help users determine which windows had an increased time cost to open. Only one window could be viewed at a time and one window covered the full screen.

### Materials

Each trial consisted of four information fields to be entered: two amounts and two account codes. Both the amounts and account codes always had the same length and though they were generated for use in this study, they were designed to look similar to the numbers seen in Studies 1 and 2. People usually worked with the same 20 or 30 account codes which consisted of six digits. They were aware they worked with the same set, but still had to look them up each time they needed them. The string of digits was random with no pattern and had a length of six digits, which made them difficult to remember.

An experimental session consisted of 50 trials, divided into 5 blocks of 10 trials. For each block, a set of 20 different amounts and 20 different account codes were used. These sets were re-used for every block, so in total, each number was presented five times throughout a session. There were two practice trials before the experiment began. The numbers used in the practice trials were not used for the experimental trials.

The experiment was conducted on a desktop computer with a 24-inch monitor with a resolution of 2048 x 1152 pixels. People used a computer mouse and number pad to view

Claim form   Amount   Account code   Amount   Account code

**Claim form**

Claim number	Amount	Account code
1	Am1	Acc1
2	Am2	Acc2

Submit

(a)

Claim form   Amount   Account code   Amount   Account code

**Amount**

Claim number	Amount
1	11.49

(b)

Claim form   Amount   Account code   Amount   Account code

**Claim form**

Claim number	Amount	Account code
1	11.49	
2		

Submit

(c)

**Figure 4.6:** Participants had to enter four data items in a data entry form (a). Each item had to be retrieved from a separate window (b) and entered into the form (c).

and enter the numbers, and the option to copy and paste information was disabled. The cursor stayed in the same cell of the data entry form if the participant switched to other windows and back.

The study was conducted in a web browser, and the task interface was developed in HTML, CSS, Javascript and PHP. The browser window was maximised to avoid distractions. All mouse clicks, keypresses and their timestamps were recorded using Javascript.

## Design

The experiment was a between-subjects design with one independent variable, the IAC of the information source windows. In the control condition, there were no delays in opening the windows. In the other two conditions, there was a two-second delay before two of the four windows were revealed. In one condition, there was a delay for viewing the two account codes, whereas in the other condition there was a delay for viewing the

two amounts. The dependent variables were trial completion time, number of visits to the information sources, and errors. In addition, all window switches and key presses were logged to determine the strategies that people used.

### **Procedure**

The experiment took place in a closed quiet room. People were welcomed and briefed verbally about the study. After reading an information sheet and signing a consent form, they completed two practice trials. After this they completed 50 experimental trials that each consisted of four entries, so in total they made 200 entries. After every 10 trials, there was the opportunity to take a break. A prompt appeared on the computer screen and time stopped. Participants decided themselves whether and how long to take a break for, and continued the experiment by pressing a 'Next' button on the screen. Participants were instructed to complete the task as fast and accurately as possible, but other than this instruction, it was emphasised they were free to use whichever strategy they wished. Examples of possible strategies were given: they could enter it per row, per column, and could go back to the information sources as often as they wished. The experiment took approximately 30 minutes.

### **Pilot study**

Two pilot studies were conducted with colleagues of the researcher to test the experimental design. In particular, the pilot studies aimed to see if the length of the experiment was long enough for participants to learn and develop strategies, but not too long to tire the participant.

During the pilot studies, there was a scheduled break after every 5 trials. Both participants mentioned the break prompts happened too frequently, and were disruptive for completing the task. They did not find the experiment too long. One participant could not remember which computer tabs had an increased IAC. As a result, he did not adapt his strategies according to anticipated IACs and entered the numbers row by row. He was aware some of the numbers occurred more than once, but the numbers did not occur often enough for him to memorise them. The second participant mentioned that the increased IACs definitely made her more careful in checking the numbers were correct.

For the real experiments, the breaks were reduced to happen after every 10 trials. In addition, the names of computer windows with an increased IAC were underlined. This visual feature was added to help users determine which tabs had an increased time cost to open.

### **Hypotheses**

Based on previous IAC studies and findings from Study 3, the following hypotheses are made:

- As IAC increases, people try to memorise and copy over more data from one source in one go.
- People will be slower and make more errors if there is an increased IAC.

The soft constraints hypothesis predicts that people choose and adapt their task strategies in order to minimise time. Based on this theory, and findings from Study 1 and 2 that people try to save up data entry tasks to enter them in one sequence, and enter items that are nearby in the environment first, the following hypothesis is made:

- As the experiment progresses and people become aware how costly it is to access certain sources, they will learn and choose to enter all the low-IAC items first, in a batch, and then the high-IAC items second, also in a batch, rather than looking up each item as they need it.

## Analysis

One-way ANOVAs were used to determine if there were significant differences between conditions in trial completion time, number of visits to the information sources, and errors.

In order to analyse if there was a significant difference in the order in which people looked up and entered data, a bottom-up approach was taken to first categorise people's strategies into different strategy categories.

All window switches and key presses were logged and saved in a spreadsheet. This log showed the order of actions for each participant and trial. There were eight different possible actions: viewing the first amount, viewing the second amount, viewing the first account code, viewing the second account code, entering the first amount, entering the second amount, entering the first account code, and entering the second account code.

There were 33 participants who each completed 50 trials, so in total there were 1650 logs. Each instance was first categorised according to the order in which items were entered: per row, column, or another order. This was to determine whether people entered and grouped data per type of data item, if they entered data in the sequence in which it was presented on the form, or if they grouped according to the IAC.

The logs were then categorised according to whether they visited multiple items before they entered them, or if they viewed and then entered each item one by one. This was to determine people's switching strategies between entering and visiting data.

## 4.2.3 Results

### Ordering strategies

Condition	Row	Column	Other	Total
High-Account	37.72% (208)	60.76% (334)	1.52% (8)	100% (550)
High-Amount	65.41% (360)	34.38% (189)	0.21% (1)	100% (550)
Control	64.39% (354)	34.75% (191)	0.85% (5)	100% (550)
Total	56.90% (922)	42.28% (714)	0.82% (14)	100% (1650)

**Table 4.3:** The rates (and frequencies) of ordering strategies per condition.

Table 4.3 shows the number of trials where people grouped per row, per column and where they had another order. The row strategy meant that the participant first entered Amount and Account1, and then Amount2 and Account2. The column strategy meant that the participant first entered Amount1 and Amount2, and then Account1 and Account2.

A chi-square test showed that the type of strategy was significantly associated with the condition,  $\chi^2(1) = 20.41$ ,  $p = 0.003$ . People most often entered data in the order in which they were presented, per row. In the High-Amount and Control condition, this strategy

(a)

(b)

**Figure 4.7:** The order strategies. (a) If people entered Amount 1 and then Account1 (or Amount2 and then Account2), this was categorised as a 'Row' strategy. (b) If people entered Amount 1 and then Amount2 (or Account1 and then Account2), this was categorised as a 'Column' strategy.

was chosen on 65.40% and 64.39% of the trials, respectively. In the High-Account condition, the strategy was chosen 37.72% of the time. In this condition, people more often entered items per column.

If people entered items per column, they would enter amounts first, even in the High-Amounts condition. In this condition, there were only three out of 189 trials where the account codes were entered first. In the other two conditions, the amounts were entered first in all trials.

### Grouping strategies

Condition	Grouped	One-by-one	Total
High-Account	25.64% (141)	74.36% (409)	100 (550)
High-Amount	38.19%(210)	61.81% (340)	100 (550)
Control	26.82% (148)	73.18% (402)	100 (550)
Total	30.24% (499)	69.76% (1151)	100 (1650)

**Table 4.4:** The rates (and frequencies) of grouping strategies per condition.

IAC had a significant effect on total number of visits to information sources ( $F(2, 32) = 63.83, p < .05$ ). People made more visits in the control condition ( $M = 5.47, SD = 2.21$ ) than when the IAC to account codes ( $M = 4.28, SD = 0.90$ ) or amounts ( $M = 4.76, SD = 1.61$ ) was increased. To see if people reduced visits by viewing multiple windows before entering any data, strategies were categorised into so-called 'Grouped' and 'One-by-one' strategies. If participants grouped visits and made multiple visits before entering them, they were placed in the 'Grouped' category. If they visited and then entered each item one by one, they were placed in the 'One-by-one' category.

Overall, for the majority of the trials (70%) people visited and entered the numbers one by one (see Table 4.4).



Condition	Grouped	One-by-one	Total
High-Account	25% (84)	75% (250)	100 (334)
High-Amount	65.24% (123)	34.76% (66)	100 (189)
Control	50.92% (97)	49.08% (94)	100 (191)
Total	44.09% (304)	55.91% (410)	100 (714)

**Table 4.5:** The rates (and frequencies) of grouping strategies for trials where people entered items in column order.

Condition	Grouped	One-by-one	Total
High-Account	26.85% (56)	73.15% (152)	100 (208)
High-Amount	23.72% (85)	76.28% (275)	100 (360)
Control	13.91% (49)	86.09% (305)	100 (354)
Total	20.45% (190)	79.55% (732)	100 (922)

**Table 4.6:** The rates (and frequencies) of grouping strategies for trials where people entered items in row order.

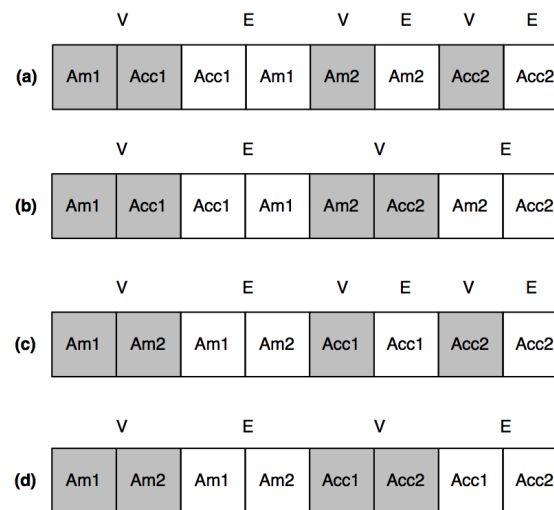
However, looking at the trials where people grouped per column, in Table 4.5 it can be seen that in the High-Amount condition, people more often tried to group. They first viewed both amount items, before they entered them. A chi-square test showed that looking at trials where people ordered per column, grouping strategy was significantly associated with condition,  $\chi^2(1) = 85.90$ ,  $p < 0.05$ .

Finally, for the trials where people decided to enter items row by row, they most often entered them one by one and did not group them, as can be seen in Table 4.6:

Condition	Row		Column		Other	Total
	First row (a)	First & Second row (b)	Amounts (c)	Amounts & Accounts (d)		
High-Account	34% (48)	4% (6)	57% (80)	2% (3)	3% (4)	100 (141)
High-Amount	20.99% (44)	16.57% (35)	49.72% (104)	9.39% (20)	3.31% (7)	100 (210)
Control	11.2% (16)	21.6% (32)	54.4 (81)	12% (18)	0.8% (1)	100 (148)
Total	21.18% (190)	15.02% (73)	52.96% (265)	8.37% (41)	2.46% (12)	100 (499)

**Table 4.7:** The most common grouping strategy was to chunk the items into three groups. The strategies are shown graphically in Figure 4.8.

In the trials where people grouped, they most often made three visits: for example, they first visited Amount1 and Amount2, and then entered Amount1 and Amount2. They then viewed Account1 and entered it, before they viewed Account2 and entered it. Figure 4.8 illustrates the most common grouping strategies. Table 4.7 shows the frequency with which these strategies were chosen per condition.



**Figure 4.8:** The sequence of the most common grouping strategies. V = visit to the data source, E = entry of the data item. For example, in Strategy (a) a participant first viewed Amount1 and Account1, and then entered Amount1 and Account1. He/she then viewed Amount2 and entered it, and then viewed Account2 and entered it.

### Performance measures: errors and speed

There was a significant difference in errors ( $F(2, 32) = 12.61, p < .05$ ), with the most errors occurring in the control condition. A post-hoc test showed there was a difference between the control condition ( $M, SD =$ ) and the two high IAC conditions, but no difference between the two IAC conditions. The error rate in the condition where the IAC for amounts was increased was 3.95 %, 4.6% in the condition where the IAC for account codes was increased, and 7.25% in the control condition.

There was no significant difference in time it took to complete a trial ( $F(2, 32) = 0.81, p > .05$ ).

### Qualitative findings

Participants mentioned adapting their strategy several times throughout the experiment, in order to find the quickest way to complete the task. Because amounts were shorter and easier to remember, several participants mentioned they tried to first view all amounts before entering them. They tried this strategy with account codes as well, but these were longer and therefore it was more difficult to memorise two at a time. As a result, most participants ended up viewing and entering each account code one by one.

Several participants noticed that numbers re-occurred throughout the experiment. They felt it was easier to memorise a number that had already occurred earlier in the experiment, so when a trial contained a number they had entered before, they would use the 'Grouped' strategy: they viewed another window and item before returning to the entry form. Furthermore, some participants started a trial by not viewing any other windows, but re-entering the data items of the previous trial in the data entry form. They would then visit the information source windows to check if the items were the same, or if they needed to change some of the items.

#### 4.2.4 Discussion

The aim of this study was to investigate the effect of IAC on how people manage subtasks to look up information from multiple information sources with varying IACs. IAC influenced the order in which people entered data and whether and how they chunked data items.

##### Strategies

IAC had an effect on people's ordering strategies, but only in the condition where the IAC was increased for accessing account codes. People first looked up and entered the low IAC items, the amounts, before they entered the high IAC items, the account codes. However, if the cost to access the amounts was increased, people entered items row by row, as participants did in the control condition.

IAC also had an effect on how often people switched between visiting and entering information. In the conditions where the amounts were low, people often visited multiple items before returning to the entry interface. Though there was no difference in errors in the current study, it can be imagined this strategy is more risky as people are away for longer so resuming a task is more difficult, and they are storing more information in memory, so people may misremember information.

In the condition where the IAC for amounts was high, this strategy was not used as frequently. IAC thus does not have to be bad if the information is easy enough to briefly hold in memory (condition amounts high).

IAC made people change strategies even if only two of the four information sources had an increased IAC. This is in accordance with (?), who showed that a more memory-based strategy can be trained for future situations. When people were exposed to an interface with an increased access cost, they adopted a memory-based strategy and retained this strategy, even when they then interacted with an interface with lower access costs.

In previous studies, people would postpone or not address information needs if there was a high time cost associated with it (Sohn, Li, Griswold, & Hollan, 2008). This was also found in Study 2. People initially tried to do tasks as they needed it, but if it took too long, they would put it aside.

In the current study, this was also found but the cost to memorise an item overrode the cost to access it: people would first enter the amounts, even if the cost to access them was higher. If the cost was high, they would try and memorise them both before entering them. This shows people try to minimise interleaving between viewing and entering information.

People made more visits to information sources in the control condition. However, as opposed to Study 3, this did not improve accuracy: on the contrary, people made significantly more errors in the control condition than when one of the sources had an increased IAC. Differences in IAC can thus help people be more efficient and effective in scheduling subtasks of looking up information, and reduce the number of visits they need to make.

##### Contributions

Demonstration that:

- IAC also affects people's strategies of switching between entering and looking at the target source when multiple sources are involved.

- IAC affects how people manage subtasks of looking up information in a data entry task.
- Depending on users' experience and awareness of how costly it is to access information, they optimise costs by processing all the low-IAC tasks first, in a batch, and then the high-IAC tasks second, also in a batch, rather than switching between the two different types of task.

## Conclusion

This study investigated the effect of IAC on looking up information from multiple sources, and showed that, if all information has the same IAC it is better if this is low, differences in IAC between sources can make people schedule their subtasks more efficiently and effectively. People needed less visits and made fewer errors. However, for this study people only had one data entry task at a time to focus on, and the sources only contained information for this single task. In Study 1 and 2, people often batched and saved up multiple data entry tasks, and sources included more than just the information for one task: for example, if people had to look up an account code, this was often retrieved from a spreadsheet with all account codes. They thus not only had to manage subtasks of one data entry task, but had to coordinate multiple data entry tasks. In order to save visits, people may therefore look up information for several tasks and interleave. One of the participants from Study 1 shared that this did occur and said she and colleagues had to be very careful to not input information in the wrong form. If people group information subtasks per IAC for a single task, would they also group these subtasks per IAC when dealing with multiple tasks? In order to answer this question, a follow-up study was run to see the effect of IAC on interleaving behaviour between two claim forms.

## 4.3 Study 5: Interleaving between data entry tasks

### 4.3.1 Introduction

Study 4 showed that people group subtasks of looking up information according to the information's IAC: if all information sources were equally easy to access, participants looked up and entered information for a task in sequential order. However, if some sources were more costly to retrieve, people first retrieved and entered all low IAC items, before they retrieved high IAC items. If people deal with multiple data entry tasks, would this also make people more likely to look up and enter low IAC items across tasks, rather than completing one task at a time? In Study 2, participants saved up data entry tasks to do in one session and occasionally had multiple data entry tasks open at the same time. Multi-tasking between data entry tasks is a common occurrence, but this strategy can be prone to errors. The aim of the current follow-up study is to see if differences in IAC between information sources makes people more likely to interleave between data entry tasks.

The following question will be addressed:

What is the influence of IAC on interleaving between data entry tasks?

(a)

(b)

(c)

(d)

(e)

**Figure 4.9:** Participants had to enter two data entry forms per trial, each containing two items. (a). The amounts for both forms had to be retrieved from one window (b) and entered into the form (c), while the account codes had to be retrieved from a second window (d) and entered (e).

### 4.3.2 Method

#### Participants

Thirty-two participants (seven male) with a mean age of 25 years ( $SD = x$ ) took part in the experiment. They were recruited from a university subject pool and received £4 for their participation.

#### Materials

The task was similar to the one used in Study 4 but differed in two aspects. Instead of filling in one data entry form per trial, people filled in two forms per trial. Furthermore, instead of four sources, participants in the current study had to retrieve information from two sources: one source to retrieve amounts, and a second source to retrieve account codes. The aim of this follow-up study was to investigate if differences in IAC of the two sources makes people more likely to interleave between data entry tasks.

#### Design

The experiment was a between-subjects design with the IAC of the information source windows as the independent variable. In the control condition, there were no delays in opening the windows. In the second condition, there was a delay for opening the window that contained the account codes. In the third condition there was a delay for viewing the amounts. All window switches and key presses were logged to determine the order in

Condition	Interleaving rate	Error rate	Trial completion time (s)
	M (SD)	M (SD)	M (SD)
High-Accounts	66.6 (3.39)	6.5 (1.04)	33.96 (5.08)
High-Amounts	85.4 (2.17)	2.9 (0.25)	33.67 (8.68)
Control	40.88 (4.03)	4.9 (0.45)	27.66 (3.40)

**Table 4.8:** Results of the dependent variables for the three conditions. The rates are percentages calculated as the ratio of occurrences to the number of opportunities.

which participants accessed the windows and entered the data items. In addition, the number of errors and trial completion time were measured.

### Procedure

The experimental setup was similar to Study 4. For each experimental trial, participants had to complete two forms with two entries each, an account code and an amount. They were instructed to complete it as fast and accurately as possible. It was explained that they could use any strategy they wanted, but that they had to complete both forms, before continuing to the next trial. The experiment took approximately 30 minutes.

### 4.3.3 Results

Three participants were removed from the data due to extreme values on performance measures. P28 and P23 made at least one error on every trial. They made 118 and 153 errors out of 200 error opportunities, respectively. P26's session was terminated before the end had been reached, as 45 minutes had passed. This participant spent on average 65 seconds per trial, which is twice as long as the mean trial time of other participants.

These three participants were considered outliers and removed from the data. Data of the remaining 29 participants was taken into the data analysis.

Table ?? shows a summary of the results of all three conditions for the dependent variables. Kruskal-Wallis tests were carried out to test if there were significant differences between the conditions.

### Interleaving strategies

Participants' data entry strategies were categorised in one of two categories: they either interleaved between the two data entry forms (e.g. entering amount on Form1, followed by entering the amount in Form 2), or they filled the forms in sequential order (entering amount and account code on Form1, followed by entering the amount and account code on Form2).

Table ?? shows the frequency of strategies per condition. In total, the strategy was chosen on 333 trials in the High-Account condition, 427 trials in the High-Amount condition, and 184 trials in the Control condition. In other words, the strategy was chosen on 66.6%, 85.4% and 40.88% of the trials, respectively. A Kruskal-Wallis test shows there is a significant difference between the different conditions,  $\chi^2(2, N = 29) = 6.68, p = 0.035$ . Mann-Whitney U tests were used to get further insight in pairwise differences between conditions. Participants interleaved significantly more often in the High-IAC conditions

Condition	Interleaving	No interleaving	Total
High-Account	333	167	500
High-Amount	427	73	500
Control	184	266	450
Total	944	506	1450

**Table 4.9:** The number of trials in which participants interleaved for the three conditions.

than the Control condition ( $U = 138$ ,  $p = 0.02$ ). There is no significant difference between the High-Account and High-Amount condition ( $U = 32$ ,  $p = 0.18$ ).

A chi-square test shows that the frequency of interleaving strategy was significantly associated with the condition,  $\chi^2(2) = 207.29$ ,  $p < 0.05$ .

### Speed and errors

There were 200 data entries, so in total there were 200 opportunities for a participant to make a data entry error. The error rates were calculated as the number of errors divided by the number of entries.

In total, 130 errors were made in the High-Account condition, 58 in the High-Amount condition, and 88 errors in the Control condition. The mean error rate was 6.5%, 2.9% and 4.9%, respectively. Looking at the total number of data entries, there was no significant difference in errors,  $\chi^2(2, N = 29) = 0.95$ ,  $p = 0.62$ .

An alternative error rate was calculated based on the number of erroneous trials. If a participant made a mistake on all four entries of a trial, this rate would consider it as one error, rather than four errors. Looking at the number of trials on which an error was made, there was no significant difference either,  $\chi^2(2, N = 29) = 0.80$ ,  $p = 0.67$ . In total, there were 87 erroneous trials in the High-Account condition, 41 trials in the High-Amount condition, and 65 trials in the Control condition. In other words, errors were made on 17.4%, 8.2% and 14.4% of the trials, respectively.

There was a significant difference in the time it took participants to complete a trial, Kruskal-Wallis chi-squared = 7.087,  $df = 2$ ,  $p$ -value = 0.02891. Mann-Whitney U tests show participants took longer in the High-IAC conditions than the control condition ( $U = 145$ ,  $p = 0.008$ ). There is no significant difference between the High-Account and High-Amount conditions ( $U = 57$ ,  $p = 0.63$ ).

### 4.3.4 Discussion

The aim of this study was to see if an increase in IAC makes people interleave more between data entry tasks. In contrast with Back, Cox, & Brumby (2012), who found that an increase in IAC made people less likely to interleave between two data entry tasks, participants in the current experiment interleaved more as IAC increased.

This may be due to the presentation of the information. In Back et al. (2012)'s study, people had to retrieve all information for both data entry tasks from one sheet. If the sheet was nearby, participants read one item at a time, and interleaved between tasks on 59% of the trials. As the cost to access this source increased, they chunked the data items associated with one task, and then after completing this task, returned to the source to chunk data items for the second task. However, in many situations, such as the office

setting of Chapter 3, information is not in one location, but different information sources have to be consulted for different types of information. For an expenses task, amounts and account codes are not on one sheet, but people have to consult one spreadsheet for account codes, and another source to retrieve the amounts. The current study looked at people's interleaving behaviour when retrieving items from multiple sources. If there were no delays in accessing these sources, participants completed one task at a time on 59% of the trials. If there was a delay in accessing either one of these sources, people tried to enter all information from this source after one visit, so they did not have to open it again. They chunked the data items associated with one source, rather than task. They first entered either Amount1 for Form1, Amount2 for Form2, and then the accounts, or first entered Account1 for Form1, Account2 for Form2, and then the amounts.

Whereas in Study 4 people became more accurate by chunking data items according to IAC, there no longer was a difference in errors in the current study. Chunking by data items in this set-up meant people interleaved between tasks and started a second task before completing the first task, a strategy which can be prone to errors (). People may forget steps, or enter correct information in the wrong fields.

It can be argued that the design of the materials encouraged participants to always group per source, regardless of the condition. However, in the Control condition there was an almost even distribution of strategies, and participants interleaved 40% of the trials. The majority of the time participants still chose to complete one task at a time.

### 4.3.5 Conclusion

People have to regularly switch between looking up information for a data entry task and entering it. The three studies described in this chapter showed how strategies to look up and enter information are influenced by the time cost to access information sources. It also showed that certain strategies are more accurate or efficient than others. The main effect of an increased IAC is that people try to minimise (re)visits. If the time to access a source increases, people will try to copy over more information after one visit. If they do not memorise it well, errors increase (Study 3). If information is spread across different sources and the IAC differs between these sources, people group visits and first look up and enter low IAC items, before entering high IAC items. This not only made them more efficient, but it also reduced errors (Study 4). However, if they have to manage multiple data entry tasks, this strategy means that they will interleave between tasks (Study 5).

These results are partly in line with observations from the first two studies. Whereas people would look at the physical receipts while typing it in, they would hold other items in memory and barely used tools to offload memory. They would first enter all items on the physical receipts. For digital information however, they would look it up as they needed it, even if IAC differed between these sources, and it could sometimes take a while before they had retrieved the information.

It seems that it is better to be able to reduce IAC and have task information ready at hand, so people do not need to switch back and forth to a source that takes time to access. There are solutions, such as increased screen space, multiple screens, or having a physical copy and placing it nearby. It was interesting to see in the first two studies that people did decrease IAC for physical items, but not for digital ones. People had a second screen, but used their primary screen to look up information because they perceived it as quicker. In this case, the cost to decrease IAC by placing information on a second screen, outweighed the cost to look it up, hold it in memory, and go back to the primary screen. However, they often did not know the associated time cost to access it, so could be away from the screen for a longer time than anticipated.

There is a need to better support people in decreasing IAC without tasking them with



the added responsibility of re-arranging different tasks, information sources, devices and screens. They should be able to do their job and have task information at hand more seamlessly.

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