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# Integrating and Evaluating Graphic Premises On-line

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## Abstract

We study the effect of redundant and integrative information on the evaluation of a conclusion. Parameters of presentation of premises try to emulate those conditions most frequently used in in-vehicle signing systems, where premises give diagrammatic and graphic information, displayed item-by-item. Results show that the evaluation of a conclusion is slower when information from the premises can be integrated than when it cannot. Redundancy of the information in different premises is only effective when it avoids the integration of information.

## Keywords

Reasoning, Integration of information, Traffic signs.

## Introduction

What is the best way to display premises to make inferences? In some circumstances we cannot go back to consider previous premises because they have disappeared. This happens, for example, with in-vehicle navigation systems. Traditional studies in reasoning used almost exclusively linguistic information in the logical arguments that are present throughout the making of an inference. On the other hand, in present-day signalling systems, on-line pieces of information are displayed for only a few seconds in a different format: maps, diagrams or drawings. It is assumed that this format facilitates making faster inferences.

Research in thinking and reasoning provides us with an excellent starting point for estimating the difficulty of an argument and the easiest way of arranging our premises to evaluate a conclusion. However, one of the most relevant factors in designing the format and the order of the information in on-line information systems is the nucleus of the discrepancy between reasoning theories: how premises are represented and integrated. Mental model theories assume the construction of analogical representations. Although there is not a clear definition of the process of integration of the premises and the conditions that influence it, they seem to depend on the repetition of components in the models (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1993). Moreover, some authors have proposed that particular repetitions of elements inside the models lead to the integration of premises (e.g. Johnson-Laird, Girotto, Legrenzi, 2004, pp.644-645). Mental-logic theories propose that information in the premises is translated into a propositional language and some schemes or mental rules acts

on this (Braine and O'Brien, 1998; Rips, 1994). Therefore the format of the premises should not have a dramatic effect on deduction. Although reasoning theories provide us with interesting and consistent predictions about general phenomena in deduction, in this case they do not offer unambiguous and consistent predictions about redundancy and integration.

In reasoning tasks it has been asserted that in some (but not all) circumstances, people hold premises separately without integrating them, but in others this is not so (Johnson-Laird and Bara, 1984, see also Gutiérrez, García-Madruga, Carriedo and Moreno-Ríos, 2000). Also, Maybery, Bain and Halford (1986), using linguistic premises with relational problems and with a concurrent task (detecting a sound), showed that when the premises could be integrated with previous ones (e.g., Mike is taller than John, John is taller than Tom), reasoners took longer to process the premises than to process non-integrative premises (e.g., Mike is taller than John, Dan is taller than Tom). Likewise, in a study in which people have to form a chain of transitive relations from multiple conditional premises, Gutiérrez, García-Madruga, Carriedo and Moreno-Ríos (2000) confirmed that the integration of new information in the third premise consumed more time for two-model problems (for instance, if e then b, if a then b, if b then c, if c then d) than for one-model problems (for instance, if a then e, if a then b, if b then c, if c then d). Therefore, integration is a time-consuming operation and the more alternative models are yielded by the comprehension of premises, the more demanding the integration process will be.

Our aim in this study was to explore the conditions that maximise the information given by premises, assuming that those presentations that are simpler in terms of quantity of information shown and faster to process are the best. A basic question here is whether the repetition of information in two premises should be avoided.

More specifically, in this study we tried to examine: 1) whether redundancy in the information given by premises influences the evaluation of a conclusion, and if so, 2) whether the integration of information has any cost in processing time and whether redundancy is effective when it avoids having to integrate information. In this study we used the simplest deductive task: participants had to evaluate the sufficiency of a conclusion, that is, whether the conclusion was consistent with the premises. They did not have to

evaluate the necessity (whether it was the only conclusion consistent with the premises). Thus, in the present study we explored how redundancy and integrative information influence the evaluation of a conclusion. To do so, we used a task similar to that used by Moreno-Rios and Garcia-Madruga (2002) but using pictures as premises.

### Study

Figure 1 represents the two conditions of interest in this study. Participants are required to think about the order of the set of three balls (blue, black and red). To carry out the experiment, we display every premise for two seconds (premise 1). The first premise in the example tells participants that there is a blue ball on the left and nothing is said about the other two, which are covered by a rectangle. When premise 1 disappears from the screen, the second drawing (premise 2) is shown, also for two seconds. In this case, it informs participants that the black ball is in the middle. Lastly, the conclusion is shown: the complete arrangement of the three balls. Participants have to decide whether this is congruent with the information given by the premises. In our example, the correct answer is “yes, it is possible”.

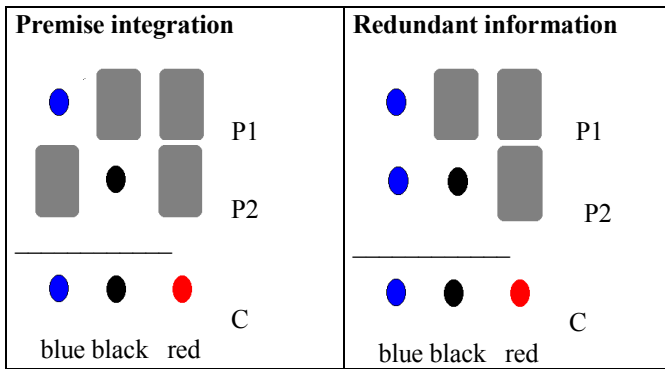


Figure 1: Premises (p) shown one-by-one, informing participants of the arrangement of three balls. They had to evaluate whether the final arrangement (C: conclusion) was possible.

In figure 1, the information offered by the two conditions is identical. However, only the first condition requires integration of the information given by the two premises. The second (premise 2) has the complete information. The mental operation for integrating the information could be a very rapid and automatic process, which could be carried out while on-line information is being shown. However, as seems to happen with linguistic information in the studies cited (Maybery et al., 1986) this process may not be automatic and can slow down the evaluation of the conclusion. Also, people might avoid integrating premises, maintaining both pieces of information separately. Therefore, our question is whether graphic or diagrammatic premises can be integrated. That is, whether the evaluation of the conclusions takes longer with integrative premises.

However, the two conditions differ from each other in more than just the necessity for integration. In the second condition there is repetition of one unit of information (the presence of the blue ball on the left). A possible difference in the evaluation time for the two conditions could be due not only to integration but also to redundancy. Therefore control conditions were created (see Figure 2). Both give the same information about the position of only one ball and the only difference is that the second one gives redundant information. This condition enables us to detect the possible effect of redundancy without integration in our study.

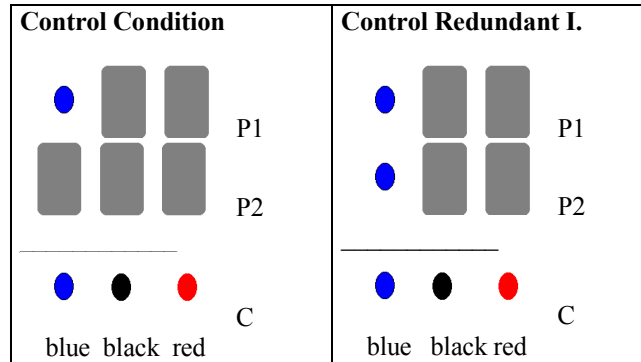


Figure 2. Control conditions with information about only 1 ball.

### Method

**Participants:** 31 male and female students from Granada University took part. They received experimental credits as compensation for their participation. All were students, registered in the first year of a developmental psychology course. All had normal or corrected vision. The participants did not know the objectives of the research.

**Stimuli and apparatus.** Both the presentation of stimuli and the collection of responses were controlled by the E-Prime, Version 1.1. (Schneider, 2003) software. Stimuli were displayed on the computer screen. Each configuration of stimuli consisted of a chain of three balls (red, blue and black) located in the left, right and central positions. The premises offered information about the relative position of the balls, showing them, or showing a grey rectangle that covered them in some of the three positions.

**Material.** The instructions encouraged participants to pay attention to all the premises. The stimulus set was constructed by changing the name and position of all the three balls. Two experimental conditions were created: in the premise integration condition the first premise showed one ball and the second one showed another ball. In the experimental redundant condition the second ball was shown adding the ball shown in the first premise. Two control conditions showed the position of only one ball in the first premise. The second premise was the same in the control redundant condition and none were shown (the three positions covered) in the control condition. In half of the trials all the premises

were inverted (first premises were changed for the second premises). Conclusions were possible in half and impossible in the other half. In addition, for half the trials the conclusion was a complete configuration showing the three balls, and in the other half only one ball was shown (and the other two were covered).

**Procedure.** The session began with the reading of the instructions informing participants about the nature of the task. These instructions provided an example corresponding to each of the experimental conditions. Participants then carried out one block of practice tests before beginning the experimental block of tests. In eight training tests, each premise remained on the screen for two seconds. When participants made a mistake the programme gave feedback indicating the correct premise. Once the most informative premise was identified, participants pressed the appropriate key. The word "ERROR" appeared on the screen when the incorrect key was pressed. Feedback about errors was given only in this practice block; the objective of this feedback was to facilitate correct identification of the premise's meaning. The conclusion was displayed, followed by the question: "Is it possible?", which remained on the screen until the response was given. The response was made by pressing the keys labelled "yes" and "no". Each test began when participants pressed the space bar. The experimental block consisted of 80 experimental trials presented in random order. Half of these were experimental trials and the other half were control trials. The content of the premises determined the possible and impossible conclusions (true and false), leading to two types of trial. In half of the trials the correct answer was "YES", and in the other half it was "NO". Adhesive labels with the words "Yes" and "No" were stuck on the "F" and "I" keys of the keyboard, respectively, in one order for half of the participants and in the other order for the rest.

## Results

Errors accounted for less than 5% of the overall responses. Reaction times shorter and longer than 3 standard deviations calculated for each individual subject were eliminated. An ANOVA (analysis of variance) was carried out on the reaction time for correct responses of possible conclusions for the factors Premise Integration (integration Vs no integration). Evaluation time was slower for the integration condition (1329ms) than for the non-integration condition (1134ms) [ $F(1,30)=40.2$ ;  $MSe=13238$ ;  $p<.00001$ ].

Another ANOVA was carried out with the control conditions to evaluate the effect of the repetition of information. In this case the variables were Premise repetition (repetition Vs non-repetition). Repeating the information (1158) of a previous premise or not repeating it (1169) did not show significant difference in the evaluation of conclusions [ $F(1,30)<1$ ;  $MSe=10939$ ;  $p>.4$ ].

## Discussion and Conclusions

The integration of information is a basic process in reasoning. The effect of premise presentation has been tested in deduction (e.g., Girotto, Mazzocco and Tasso, 1997; Legrenzi, Girotto and Johnson-Laird, 1993) but the process of integration needs to be studied in detail. This knowledge could be especially interesting for a growing area in communication in daily activities, such as driving using in-car navigation systems or reading variable-content signing systems. Similar conditions in the way of presenting information were used in this study to analyse the effect of presentation of redundant information (repetitions) and to know whether the integration of information about an event is made in an automatic way producing the slowing down of later processing.

The results of this study showed that when information from the premises needed to be integrated, the evaluation of the conclusion took longer than when one of the premises contained all the information (integration was not required), according to Maybery et al's (1986) results with a relational propositional task and Gutiérrez et al's (2000) results with multiple conditional problems. Also, the control condition showed that redundant information (repeating the information in a premise) *per se* did not influence the evaluation time of the conclusion.

We think that this result is interesting in two aspects: in the studied conditions, which are frequently used for communication systems (that show premises one-by-one for few seconds), repetition of information does not necessarily facilitate the comprehension or the evaluation of conclusions. However, when different pieces of information have to be integrated the evaluation is slower. It is in this case, when the repetition of information allows us to avoid the operation of integrating information, that redundancy is more effective in the evaluation of conclusions. This happens even with very simple information such as that shown in the present study.

The main deductive theories coincide with each other, predicting the main results in reasoning, although in some cases they describe the processes implicated in a different way. Unfortunately, they do not give a complete and clear description about how people integrate information from the premises. The present results could be accounted for by the two main theories in reasoning (the mental model theory and mental logic theories). However we think that the mental model theory can incorporate these results in a more natural and easier way. Traditional tasks designed to study deduction used linguistic premises and the main explanatory effort of the theories has been directed to this kind of task. Mental Logic theories (Braine and O'Brien, 1998; Rips, 1994) assume that premises (linguistic, diagrammatic, etc.) are translated into propositions and assigned to the appropriate schemes, losing their perceptive character. Of course, relevant perceptive aspects of the premise such as colour or location could be coded by propositions. However we think these theories predict that graphic or diagrammatic premises do not contribute to facilitating deduction. On the

other hand, the mental model theory (Johnson-Laird, 1983, 1999) seems to account for (and predict in a more natural way) thinking with diagrammatic and graphic premises. Actually advantages have been predicted for some conditions regarding linguistic premises (eg. Bauer and Johnson-Laird, 1993). This theory maintains that people represent premises in an analogical format: a mental model of the premise (such as an arrangement of three balls).

One example of how theories could help is by signalling the factors that contribute to the integration of premises or others that can incite people to maintain the information given by the premises separated in the Working Memory until they are required. From the mental model theory, it has been proposed that definition of the context is one important factor for integration (Bouquet and Warglien, 1999). It seems plausible that one way of integrating premises is by comparing elements inside the models. Anyway this study shows that whatever the explanation of the integration, even in simple cases, it takes time, which influences the evaluation of a subsequent conclusion.

To summarise, this study showed that the integration of information implies a time cost for later processing (the evaluation of conclusions). In dynamic information systems, such as in-vehicle navigation systems or similar, this delay could decrease the probability of generating important conclusions that might also be required to integrate new information. Knowing the conditions that make the integration of information easier can help us to propose theoretical models from the main theories of deduction that help us to find more general principles in this field.

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