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Perceptual inferences about indeterminate arrangements of figures

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ABSTRACT

Previous studies in spatial propositional reasoning showed that adults use a particular strategy for making representations and inferences from indeterminate descriptions (those consistent with different alternatives). They do not initially represent all the alternatives, but construct a unified mental representation that includes a kind of mental footnote. Only when the task requires access to alternatives is the unified representation reinspected. The degree of generalisation of this proposal to other perceptual situations was evaluated in three experiments with children, adolescents and adults, using a perceptual inference task with diagrammatic premises that gave information about the location of one of three possible objects. Results obtained with this very quick perceptual task support the kind of representation proposed from propositional spatial reasoning studies. However, children and adults differed in accuracy, with the results gradually changing with age: indeterminacy leads adults to require extra time for understanding and inferring alternatives, whereas children commit errors. These results could help inform us of how people can make inferences from diagrammatic information and make wrong interpretations.

1. Introduction

Some basic perceptual tasks require considering alternatives and making rapid inferences. For example when a tree hides the upper part of a traffic light and we can see that the other two circle lights are off, we can infer that the green light is on. At other times the information is indeterminate, for example, if we can see only one circle and it is off. In everyday life we detect objects by perceiving them directly in their location and by inferring them. In some cases our decisions are based on inconclusive partial information. The knowledge about how people represent and make inferences with indeterminacy can help us design signals and instructions that can be interpreted quickly and correctly. In the present study we test how adults and children cope with diagrammatic descriptions of the arrangement of three objects when the information given is indeterminate. Inferences with perceptual premises have rarely been studied. Instead, the determinacy of arrangements of objects has been studied in the psychology of thinking with propositional descriptions of objects in different locations, as in the following example:

"Think about this description of three objects ordered in a line:
The fork is on the right of the knife
The spoon is on the right of the fork"

The description is consistent with a possible arrangement "knife fork spoon". This is called a "determinate" problem. By contrast, an example of indeterminate description is:

The fork is on the right of the knife
The spoon is on the right of the knife

The description is consistent with two possible arrangements. How do we represent this description? We can construct mental models, spatial representation of the objects in this order:

Knife fork spoon
Knife spoon fork

Testing whether "knife fork spoon" is consistent with the premises is harder in the indeterminate problem than in the determinate problem. This could be because in the indeterminate problem we have to match the conclusion with two possible arrangements (two mental models) but in the determinate problem with only one. Studies corroborating the fact that inferences based on one model are easier than those based on multiple models include Schaeken, Johnson-Laird, and d'Ydewalle (1996), Vandierendonck and De Vooght (1996), Moreno-Ríos and García-Madruga (2002) and Carreiras and Santamaria (1997). Interestingly, these studies have shown differences in comprehension: it takes longer to read the indeterminate premises, consistent with more than one arrangement, than the determinate premises (see Schaeken, Van der Henst, & Schroyens, 2007).

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Some of the tasks used in spatial reasoning to study indeterminacy are not essentially deductive. For example, Rauh et al. (2005) used a verification paradigm in which participants had to decide whether a conclusion followed from the premises. That is, participants had to decide not whether the conclusion was necessary but whether it was sufficient.

A key question is how we represent the indeterminacy. Do we represent all the alternatives? This has been the goal of some studies (see Knauff, 2013). For example, Vandierendonck, Dierckx, and De Vooght (2004) studied what kind of representation is used to cope with indeterminate descriptions. They tested different possibilities such as whether people represent all the situations or some of them, or they create an annotated model that signals where the indeterminacy is located. It is improbable that people represent all the situations (also, Vandierendonck, De Vooght, Desimpelaere, & Dierckx, 2000) because that would require a high working memory load (Johnson-Laird, 2006). The other alternative is that people integrate the information in one unique representation but adding a marker for the indeterminate information, an annotation (mental footnote, Rauh, 2000). Only if further processing is required is the marker accessed. For example, the representation could be something like:

Knife (fork) spoon

The bracket means that the fork and the spoon are on the right of the knife but the relationship between the fork and the spoon is not determined. Schaeken et al. (2007) also proposed the annotated model, which they call an isomeric model, but with a difference: the indeterminate information is accessed immediately after reading the premises.

Particular interest has been shown in experimental situations where the premises are briefly displayed on a screen, one by one without the opportunity to go back. Participants have to use a specific strategy to keep the information in mind, constructing an integrated representation with the maximum possible information (Evans, Newstead, & Byrne, 1993; Roberts, 2000).

The mental model theory proposes that people represent explicitly just a part of the information, leaving the rest as implicit (Johnson-Laird, 1983). Only when it is required, do people go back to the premises and flesh out the implicit information. However people might use a different strategy in some contexts. Vandierendonck et al. (2004) proposed and tested for the possibility that in some situations the information in the premises is rapidly lost. For example when the premises are only presented briefly, one by one, with no possibility of returning to a previous premise, reasoners are faced with the requirement to keep as much information as possible in memory. In these situations people use a different strategy: one very effective way is by immediately constructing an integrated representation on-line, compressing all the information in the premises (see e.g., De Soto, London, & Handel, 1965; Evans et al., 1993; Huttenlocher, 1968; Ormerod, 1979; Potts, 1974; Roberts, 2000; Vandierendonck & De Vooght, 1996). Vandierendonck et al. (2004) affirmed that only one integrated representation is constructed from the premises. The search for counterexamples is simplified because all the information is included in the integrated initial representation. Actually, Rauh et al. (2005) found support for the integrated representation analysing the specific errors of omission and commission made with indeterminate premises.

In the present study we test two questions: do we represent indeterminate perceptual descriptions and make perceptual inferences in the same way as we do with propositional descriptions? Is it a strategy present in children, or does it just develop with experience in adulthood? Only if the answers to those questions are yes, can we study the inference process, changing the usual propositional inference tasks into perceptual tasks. This could help us test, for example, young children or adults with a lower linguistic development.

The answers to these questions can be disentangled from knowing how indeterminacy is represented. On the basis of the empirical data reviewed (Knauff, 2013; Rauh et al., 2005; Vandierendonck et al., 2000, 2004), the annotated models' view is the one favoured, and the complete models' view, at least, has been shown to be probably incorrect (Vandierendonck et al., 2000). Vandierendonck et al. (2004) asked about the generality and the robustness of these findings and whether they could be applied to other problem structures (p. 1390). The preference for the way of representing uncertainty has not yet been tested in situations that could induce alternative parameters in working memory load, strategies, etc. Here it is evaluated by: (a) using perceptual premises instead of propositional premises and (b) evaluating people of different ages. To do this, we created a new task.

1.1. The perceptual inference task

A new task was created to test how children, adolescents and adults evaluate inferences in very simple situations. In the task, participants have to think about the relative location of the following three figures:

A red triangle, a red circle and a blue circle.

In each trial, participants have to discover the order of these three figures on a line. They are given partial information (premises) about one object in one location. The premise may be determined or indeterminate. For example, if the premise is "there is a triangle on the left", the information given by the premise is determined because the only triangle among the three figures is the red one (note that the premise is not determined regarding the location of the other two figures). However if the premise is "a circle is on the left" the information is indeterminate, because we cannot know if it is the blue or the red circle. After the premise, a view of two of the three objects is displayed on the screen (conclusion) and participants have to say whether this information (conclusion) is consistent with the previous information (premise). That is, if the conclusion is possible or not, given the premise information.

Diagrammatic premises were used instead of the usual propositional descriptions frequently utilised in spatial relational reasoning tasks. The task is easy enough to be carried out by children because of the use of diagrammatic premises and the very small set of figures (just three).

Fig. 1 shows an example of the procedure in a typical experimental trial. Note that the information about some of the figures is hidden behind a black mask. The premise informs participants that there is a triangle on the left. Because there is only one triangle among the three figures, we know that there is a red triangle in the left-hand position. We also know that in the middle and on the right there are circles, but we cannot know which is blue and which red. After the premise, a conclusion is shown with a red triangle on the left and a blue circle in the middle. We can assume that the red circle is hidden behind the mask in the right-hand position. The conclusion is consistent with the premise, and therefore we have to say "yes" it is possible.

The present task uses two kinds of trials depending on the information given by the premises: shape information premises and colour information premises. The example of the trial in Fig. 1 uses a shape information premise. In other trials the premise, instead of informing about the shape (e.g. there is a triangle on the left), informs about the colour of the figure. For example, that there is a blue figure in the middle. In this case, the only blue figure is the blue circle, and therefore we know which figure is in the middle. Fig. 2 shows the kinds of premises in the experiment. The inclusion of shape and colour premises makes the task more unpredictable regarding the status of determination of each figure.

The task tests the inference process condition in relation to a control (matching) condition. Only in the inference condition, and not in the control, that premise and conclusion tell us about different figures in different locations, and therefore we have to think about alternative figures. Matching contents in one location is not enough to obtain a correct