Acta Psychologica 179 (2017) 96–103

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Directional effect in double conditionals with a construction task: The semantic hypothesis

Orlando Espino[a,*], Tarek Morales[a], Alicia Bolaños-Medina[b,1]

[a] University of La Laguna, Tenerife, Spain
[b] University of Las Palmas de Gran Canaria, Gran Canaria, Spain

ARTICLE INFO

Keywords:
Directional effect
Double conditional
Semantic hypothesis

ABSTRACT

The goal of this paper is to test the main predictions of the semantic hypothesis about the directional effect in double conditionals (such as, 'A only if B/only if C, B') with a construction task. The semantic hypothesis claims that directional effect can be explained by the inherent directionality of the relation between the relatum and the target object of the premises. According to this hypothesis, a directional effect should occur if only one of the end-terms of the premises takes the role of relatum: a) if the end-term that plays the role of relatum is in the first premise, a forward directional effect is predicted (from A to C); and b) if the end-term that plays the role of relatum is in the second premise, a backward directional effect is predicted (from C to A). On the other hand, it claims that there should be no directional effect when both end-terms take the role of relatum or when neither of the end-terms plays the role of relatum. Three experiments confirmed the main predictions of the semantic hypothesis in a construction task.

1. Introduction

Deductive reasoning constitutes the essence of the human intellect; without it, many conceptual disciplines would not be possible. However, deductive reasoning can be influenced by different factors, such as the content and logical structure of arguments. The main aim of this research is to study how the logical structure of problems affects the inferences that people make from double conditionals, such as 'if A, B and B only if C'. Several studies have shown that the logical structure of a problem could generate a directional effect in conditional inferences (Espino & Hernández, 2009; Evans, 1977, 1993; Evans & Beck, 1981; Grosset & Barrouillet, 2003; Oberauer, Hörnig, Weidenfeld,- & Wilhelm, 2005; Oberauer & Wilhelm, 2000; Santamaría & Espino, 2002), in syllogistic reasoning (Espino, Santamaría, & García-Madruga, 2000; Oberauer & Wilhelm, 2000; Oberauer et al., 2005; Quayle & Ball, 2000; Stupple & Ball, 2007), in relational reasoning (Johnson-Laird & Bara, 1984), and in tasks combining disjunctive, conjunctive, and conditional premises (García-Madruga, Moreno, Carriedo, Gutiérrez, & Johnson-Laird, 2001). Directional effect involves the fact that people find it easier to make or process inferences in one direction rather than in the other. Some authors found that in the conditional rule 'if A then B', participants make more forward inferences (from A to B) than backward inferences (from B to A), whereas for the conditional form 'A only if B', participants make more backward inferences than forward inferences (Evans, 1977, 1993; Evans & Beck, 1981). Other studies have documented that the amount of time that reasoners take to perform backward or forward inferences varies according to different conditional forms (Grosset & Barrouillet, 2003; Santamaría & Espino, 2002). Examining what causes directional effect in reasoning tasks is the key concern of the present study, since it is a critical step for understanding the nature of human reasoning. We argue that a theory of deductive reasoning would be incomplete without accounting for directional effect or biases. As we have already mentioned, directional effect has been previously documented in almost all areas of deductive reasoning: categorical syllogisms, conditional inferences, tasks combining disjunctive, conjunctive and conditional components, and relational reasoning.

In problems with two premises, the logical structure depends on the figure of the problem. There are three different terms (A, B, C) in each figure. The term that is repeated in both premises (B) is called the middle-term and the other two terms (A, C) are called the end-terms. As in the case of syllogisms, four different types of figures can be distinguished in double conditionals:

* Corresponding author at: Department of Psychology, University of La Laguna, Campus de Guajara, 38205 La Laguna, Tenerife, Spain.
E-mail addresses: oespinom@ull.edu.es (O. Espino), alicia.bolanos@ulpgc.es (A. Bolaños-Medina).
[1] Departamento de Filología Moderna, e Instituto para el Desarrollo Tecnológico y la Innovación en Comunicaciones, Universidad de Las Palmas de Gran Canaria, Edificio Anexo de Humanidades, Desp. 118, C/Pérez del Toro, 1, 35001, Las Palmas de Gran Canaria.

http://dx.doi.org/10.1016/j.actpsy.2017.07.007
Received 21 February 2016; Received in revised form 27 June 2017; Accepted 12 July 2017
Available online 25 July 2017
0001-6918/

Figure 1	Figure 2	Figure 3	Figure 4
If B, then A	If A, then B	If B, then A	If A, then B
If C, then B	If C, then B	If B, then C	If B, then C

As we have previously commented, the figure of the problem elicits a directional effect in conditionals and different hypotheses have been offered to explain such directional effect (Chater & Oaksford, 1999; Johnson-Laird & Bara, 1984; Oberauer & Wilhelm, 2000; Oberauer et al., 2005;Polk & Newell, 1995; Wetherick & Gilhooly, 1990). Following we present some of the most relevant hypotheses that have been suggested in order to explain the directional effect due to the figure or structure of the problem. First, the syntactic hypothesis (Polk & Newell, 1995; Wetherick & Gilhooly, 1990) argues that the figural effect arises from the tendency to use a term that has appeared as the grammatical subject of one of the premises as the first term in the conclusion. In figure 4 (A-B/B-C), "A" is the subject of the first premise, so the preferred order of the end-terms in the conclusion will be: A-C. In Figure 1 (B-A/C-B), "C" is the subject of the second premise, so C-A will be more frequent.

Second, the Probability Heuristic Model (Chater & Oaksford, 1999) argues that directional effect can be explained by the intervention of two heuristics: the min-heuristic and the attachment heuristic. According to the min-heuristic, individuals choose the quantifier of the conclusion to be the same as the quantifier in the least informative premise (the min-premise). A premise is more informative when what it claims is less likely to be fulfilled. For example, in real life, the premise "some things that are inside the room are black," is more likely to happen than the premise "all the things that are inside the room are black." In this case, the first premise is less informative than the second one. The attachment heuristic sets the order of the conclusion by using the following procedure: if the min-premise has an end term as its subject, this will be used as the subject of the conclusion. Otherwise, the end term of the max-premise will be used as the subject of the conclusion. On the other hand, the Probability Heuristic Model predicts that the conclusion order is determined by the conclusion type. In other words, "the order of the end term is decided after conclusion type is selected" (Chater & Oaksford, 1999, p. 212). The main limitation of both the Probabilistic Heuristic Model and the syntactic hypothesis (Polk & Newell, 1995; Wetherick & Gilhooly, 1990) is that these hypotheses have been proposed to explain directional effect in sentences in which there is a grammatical subject and predicate, such as syllogisms. However, the problems used in this research have no grammatical subject, and, consequently, no explicit prediction could be made from these two points of view.

Third, the Mental Model theory (Johnson-Laird & Bara, 1984; Johnson-Laird & Byrne, 1991) states that directional effect is due to the FIFO principle: the first element of information that enters the integrated model of the premises will be the first item in the conclusion. In the syllogism A-B/B-C (figure 4), "A" is the first term in the integrated model and, consequently, according to the FIFO principle, the most frequent conclusion will be in the A-C direction. However, in the syllogism B-A/C-B (Figure 1), "C" is the first term in the integrated model and, following the FIFO principle, the most frequent conclusion will be in the C-A direction. Nonetheless, Johnson-Laird and Bara (1984) do not predict a directional effect in figures 2 (A-B/C-B) and 3 (B-A/B-C). Contrary to previous theories, the Mental Model Theory *explicitly* posits a working memory demand induced by figure that promotes figural biases on performance' (Stupple & Ball, 2007). Recently, proponents of the Mental Model theory have claimed that the definitive account of the figural effect "is a semantic one due to Oberauer and his colleagues" (Khemlani & Johnson-Laird, 2012, p. 431).

Fourth, the semantic hypothesis (Oberauer & Wilhelm, 2000; Oberauer et al., 2005) argues that the inherent directionality of the relation between the target object and the relatum is the main factor that generates a directional effect in reasoning tasks. This hypothesis claims that most connectives used in deductive reasoning tasks have an inherent directionality. Based on the works by Logan (1994) and Gemsbacher (1991), the authors propose that the meaning of a statement "is in part represented as a set of cognitive procedures for building a representation of the situation described by a statement. These procedures start with establishing the referent of one term as a reference object that serves as the foundation of a new structure, and then proceed to add a representation of the other term as a target object in the required relation to the reference object" (Oberauer & Wilhelm, 2000, p. 1703). These authors claimed that this procedure establishes an inherent directionality in the resulting representation, "such that reasoning processes tend to start with the reference object and proceed to the target object, rather than reverse" (Oberauer & Wilhelm, 2000, p. 1703). Then, following this point of view, it is the specific meaning of every conditional sentence, instead of its common syntactic structure, which allows us to predict its inherent directionality. For example, when people read a spatial sentence, such as 'the spoon is to the left of the fork', they first identify the *fork* as the reference object and place it somewhere in the spatial coordinate system. The relation 'to the left of' is interpreted as a region to the left of the reference object, and the focus of attention is moved from the reference object into this region to detect a representation of the *spoon*. However, in the conditional 'if A, then B', the term "A" is the reference object or relatum, while the term "B" is the target object, and, therefore, this conditional shows a forward directionality, i. e. a directionality from A to the term B (A → B). On the other hand, in the conditional 'A, if B', the term "B" is the relatum, while the term "A" is the target object, and this conditional shows a backward directionality, i. e. a directionality from "B" to the term "A" (A ← B). These predictions have been confirmed by Oberauer et al. (2005, experiment 1) and Espino, Sánchez-Curbelo, and Bolaños-Medina (2015) in an evaluation task. For example, Oberauer et al. (2005) found that after reading a double conditional (such as 'if A, then B/if B, then C') participants read the categorical premise "A" faster than the categorical premise "C". However, they also found that after reading the reverse double conditional (such as, 'A if B/B if C'), participants read the categorical premise "C" faster than the categorical premise "A". According to the semantic hypothesis, the main factor that could explain directional effect "is the inherent directionality of the relation, which is preserved in the integrated model if and only if it is needed to preserve a semantic asymmetry" (Oberauer et al., 2005, p. 1245). This hypothesis can be summarized in the following way:

1) If only one end-term plays the role of relatum, then there will be a directional effect. If the end-term playing the role of relatum is in the first premise, the directional effect will be forward (from A to C). If the end-term that plays the role of relatum is in the second premise, the directional effect will be backward (from C to A). A directional effect is predicted when there is a semantic asymmetry between the relatum and the object.

2) If both end-terms, or neither of them, play the role of relatum, there will be no directional effect. No directional effect is predicted when there is a semantic symmetry between the relatum and the object.

The predicted directionality for problems in experiment 1, experiment 2, and experiment 3 according to the semantic hypothesis is presented in Table 1.

One aspect in which we differ from Oberauer et al. (2005) is that we assume that the 'if' term determines which end-term plays the role of relatum. According to our proposal, the end-term that plays the role of relatum is the end-term that follows the 'if' term. Then, we predict a directional effect from the *if-clause* to the *then-clause* for any kind of simple and double conditionals (indicative, negative and affirmative exceptive, counterfactual, semifactual, etc.) and biconditionals. However, Oberauer et al. (2005) did not predict any directional effect for the 'only if' conditional nor for the 'if and only if' biconditional. According to these authors, the 'A only if B' conditional and the 'if and only if A, B' biconditional have an indeterminate inherent