

## Graded Biconditionality and Reasoning

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In the literature on conditionals, the meaning contribution of a conditional connective (CC) has been long debated. In propositional logic, a conditional sentence (If  $p$ ,  $q$ ) is treated as material implication and 'if' is a binary truth-functional connective. Such a logical approach has been criticized a.o. in the restrictor analysis of Kratzer (1986/1991) or in the psychological theories of reasoning. For instance, Johnson-Laird and Byrne's (2002) mental model theory (MMT) of conditionals claims that people only think of true possibilities. Therefore, among the four possibilities for a conditional, namely,  $P1=p\&q$ ,  $P2=\neg p\&q$ ,  $P3=p\&\neg q$  and  $P4=\neg p\&\neg q$ , the - false - possibility  $P3$  is not considered. In comparison,  $P2$  and  $P3$  are both false possibilities in the case of biconditionals (Iff  $p$ ,  $q$ ). Thus, conditionals and biconditionals should differ w.r.t. the psychological accessibility of  $P2$ . Espino and Villar (2016), for example, tested Spanish *if* with *on condition that*, assuming that the latter is inherently biconditional (cf. Montolio 2000, Alexe 2013). In their study, subjects read scenarios containing a conditional or biconditional sentence, and later a conjunctive statement taking different forms (i.e.  $P1-4$  as above). They found that the reading time (RT) of  $P2$  primed by Spanish *on condition that* was longer than that primed by Spanish *if*, thus speaking in favor of the MMT. In the following we report two experiments in German, one on the (bi)conditionality of German CCs by checking the validity of MP (modus ponens) and AC (affirmation of the consequent) inferences and the other one on the MMT using a similar design as Espino and Villar (2016).

**Experiment 1** used a  $4\times 2$  factorial design with the factor CC (i.e. *wenn/falls/im Falle*, *dass/unter der Bedingung*, *dass* 'if/in case/in the case that/on condition that') and Inference (MP vs. AC). We used 48 items, e.g. (1), and 48 fillers (with valid and invalid inferences). We created eight counterbalanced sets and ran the experiment at [www.soscisurvey.de](http://www.soscisurvey.de). In total 96 subjects took part and rated S3 on a 5-point Likert scale (5: yes, 4: rather yes, 3: I can not tell, 2: rather no, 1: no). We had three predictions: 1) MP is valid for all the CCs, thus, C1/C3/C5/C7 should receive equally high ratings. 2) AC is only valid for *unter der Bedingung*, *dass*, thus, C8 should receive significantly higher ratings than C2/C4/C6. 3) C1 vs. C2, C3 vs. C4, C5 vs. C6 should differ significantly whereas C7 vs. C8 do not.

(1) S1: Wenn der Winterschlussverkauf beginnt, geht Nadja in die Stadt einkaufen. ('If the winter sales start, Nadja will go shopping in downtown.')

MP\_S2: Der Winterschlussverkauf beginnt. ('The winter sales start.')

MP\_S3: Geht Nadja in die Stadt einkaufen? ('Is Nadja going shopping in downtown.')

AC\_S2: Nadja geht in die Stadt einkaufen. ('Nadja is going shopping in downtown.')

AC\_S3: Beginnt der Winterschlussverkauf? ('Do the winter sales start?')

Table 1: Results of Experiment 1

Descriptive statistics			Analysis of variance (ANOVAs) by subjects and by items
Condition	Mean	SD	
C1: wenn+MP	4.72	.39	Main effect of CC: ( $F(3,93)=11.625$ ; $p<.001$ ; $F(3,45)=11.063$ ; $p<.001$ ) Main effect of Inference: ( $F(1, 95)= 101.943$ ; $p<.001$ ; $F(2(1,47)=441.406$ ; $p<.001$ ) Interaction: ( $F(3,93)=13.481$ ; $p<.001$ ; $F(3,45)=11.101$ ; $p<.001$ )
C2: wenn+AC	3.91	.73	
C3: falls+MP	4.71	.41	
C4: falls+AC	3.95	.76	
C5: i.F.+MP	4.79	.33	
C6: i.F.+AC	3.94	.77	
C7: u.d.B.+MP	4.72	.40	
C8: u.d.B.+AC	4.21	.68	
C9: valid	4.42	.50	
C10: invalid	1.43	.49	

Post-hoc paired t-tests results confirmed the first and the second predictions,

that is, the AC inference was rated as more valid with *unter der Bedingung, dass* than with the other three CCs. However, concerning the third prediction, we found that all the comparisons including C7 vs. C8 was significantly different, which casts doubt on mapping *unter der Bedingung, dass* to a logical biconditional connective.

**Experiment 2** was built on the results of Experiment 1 that *unter der Bedingung, dass* is more biconditional than the other three CCs. With the priming paradigm as Espino and Villar (2016), we used a 4\*2 factorial design, with the factor of CC (4 levels as in Experiment 1) and of Conjunction (p&q vs.  $\neg$ p&q, henceforth, pos vs. neg). We used 48 scenarios, e.g. (2), with 32 additional filler scenarios. The scenarios were divided into eight counter-balanced set. The experiment was programmed in python. 48 subjects read a set of 80 randomized scenarios presented sentence by sentence, and answered the last comprehension questions. Our prediction was that the RT of p&q did not differ among the CCs but that the RT of  $\neg$ p&q would be longer for *unter der Bedingung, dass* than for all the other CCs. As shown in Table 2, there was a significant main effect of Conjunction, but neither the main effect of CC nor the interaction was significant.

(2) S1\_Dennis kaufte einen Blumenstrauß für seine Freundin. S2\_Die Blumenladenverkäuferin hat ihm gesagt: **S3\_Wenn es Narzissen gibt, gibt es Rosen.** S4\_Als Dennis sich umschaute, stellte er fest: **S5\_Es gab (keine) Narzissen und es gab Rosen.** S6\_Dennis ließ sich einen wunderschönen Strauß zusammenstellen. S7\_Hat Dennis Schokolade gekauft?

(‘Dennis was buying a bouquet for his girl friend. The bouquet vendor told him: If there are lilies, there are roses. When Dennis looked around, he found out: There were (no) lilies and there were roses. Dennis had a wonderful bouquet made. Did Dennis buy chocolate?’)

Table 2: RT (milliseconds) of S5 in Experiment 2

Descriptive statistics			Analysis of variance (ANOVAs) by subjects and by items
Condition	Mean	SD	
C1: wenn+pos	1531	465	
C2: falls+pos	1500	429	Main effect of Conjunction:
C3: i.F.+pos	1540	547	(F1(1,47)=106.226; p<.001; F2(1,47)=197.5503; p<.001)
C4: u.d.B.+pos	1586	521	Main effect of CC:
C5: wenn+neg	2033	695	(F1(3,45)=1.1931; p=0.3147; F2(3,45)=0.6601; p=.5779)
C6: falls+neg	2157	808	Interaction:
C7: i.F.+neg	2225	926	(F1(3,45) = 1.0109; p=.3899; F2(3,45)=0.8552; p=.4660)
C8: u.d.B.+neg	2152	848	

**Conclusion and discussion:** We were not able to verify the MMT in Experiment 2 as Espino and Villar (2016). There can be different reasons for this. One good possibility is that *unter der Bedingung, dass* is not biconditional semantically. That is, it just marks the antecedent as the necessary condition as the other tested CCs. The high rating for it on the AC inference can be explained away pragmatically, e.g. by its higher tendency for conditional perfection (cf. Geis and Zwicky (1971) and subsequent works) in comparison to the other CCs. Thus, these CCs do not differ w.r.t. the psychological accessibility of  $\neg$ p&q. This explanation is compatible with the high ratings for all the CCs on the AC inference in Experiment 1, which raises further methodological questions on testing conditionals (cf. Noveck 2018).

Selected references: **Espino O. & B. Villar** (2016). Priming effect in affirmative complex conditional connectives. *Journal of Cognitive Psychology*. **Geis, M. L. & A. M. Zwicky.** (1971). On invited inferences. *Linguistic Inquiry* 2: 561-566. **Montolío, E.** (2000). On affirmative and negative complex conditional connectives. In Couper-Kuhlen, E. and B. Kortmann (Eds.), *Cause, Condition, Concession, Contrast*. Mouton de Gruyter. New York. **Noveck, I.** (2018). Conditionals. *Manuscript*. **Johnson-Laird, P.N. & R.M.J. Byrne.** (2002). Conditionals: A theory of meaning, pragmatics and inference. *Psychological Review* 109(4), 646-678.