RUNNING HEAD: PROPOSITIONAL MODELS

Propositional Models of Evaluative Conditioning

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Abstract

Although propositional models of associative learning are often referred to in the literature on evaluative conditioning (EC), it has not yet been stipulated clearly what propositional models of EC entail. The aim of this paper is to describe in more detail the assumptions of propositional models of EC. This includes a discussion of the core assumption that EC is mediated by propositions about stimulus relations, as well as assumptions about the processes via which those propositions are formed and influence liking. Based on this discussion, I put forward the Integrated Propositional Model that combines a number of these assumptions and discuss some of the predictions that can be derived from this model. The paper ends with a reflection on the limitations and strengths of propositional models of EC.

Keywords: Evaluative conditioning; propositions; learning

Propositional Models of Evaluative Conditioning

More than 40 years after Levey and Martin's (1975) seminal paper, research on evaluative conditioning (EC) is still going strong. On the one hand, it is good to witness this level of interest because EC research has the potential to shed light on how stimulus pairings shape our likes and dislikes. On the other hand, it is disconcerting to see that after so many years, there is still much debate about when and how stimulus pairings change evaluations. For many years, progress in research on EC was hampered by uncertainty about the definition of EC. Initially, EC was often considered to be a mechanism that produces evaluative associations in memory. More recently, it has been argued that EC is best defined as an empirical phenomenon, namely as the impact of stimulus pairings on liking (De Houwer, 2007). By separating the to-be-explained phenomenon from the explanatory mechanisms, the latter definition paved the way for a wider variety of ideas about the mechanisms that underlie EC effects. As is evidenced by the content of this special issue, theoretical diversity has increased substantially in the EC literature. But also this observation evokes mixed feelings. On the one hand, theoretical diversity leads to debates that stimulate new research and could thus lead to a better understanding of both moderators and mediators of EC. On the other hand, too much focus on mediating mechanisms continues to detract attention away from finally establishing practical guidelines on how EC can be deployed most effectively and efficiently in real life.

While acknowledging that EC research would benefit from an increased focus on the practical use of EC, within the context of this special issue, the current paper focuses on ideas about the mechanisms that mediate EC. More specifically, I try to clarify some of the assumptions that propositional models make about the nature of those mechanisms. The propositional models that are typically referred to in the EC literature (e.g., Mitchell, De Houwer, & Lovibond, 2009; De Houwer, 2009) were developed to account for associative learning, that is, for the impact of stimulus pairings on behavior in general. They have their roots predominantly in research on human causal learning (e.g., De Houwer & Beckers, 2002; Waldmann & Holyoak, 1992) but have often been related also to EC (e.g., Corneille & Stahl, in press; Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010; Sweldens, Corneille, & Yzerbyt, 2014). Surprisingly, however, a paper-length treaty of what propositional models of EC actually imply is still lacking. The current paper aims to advance the debate about propositional models as they apply to EC. I also put forward one instance of a propositional model that combines assumptions about different processing steps that are involved in EC effects. In doing so, I hope to eliminate some of the misunderstandings about the nature and implications of propositional models of EC that have surfaced in the literature and during many informal discussions with colleagues.

I will not, however, put forward a formalized model that can easily be falsified. Although there are advantages to having falsifiable formalized models, at least in current psychology, such models tend to oversimplify inherently complex psychological phenomena. This often results in an emphasis on moderators that are important primarily because they have the potential to falsify models while ignoring other moderators simply because the models have little to say about them. Moreover, because formalized models often have a protective belt of parameters that can be adjusted to rescue the model in the face of falsification (Lakatos, 1970), in reality most formalized psychological models are neither precise nor falsifiable when considering the class of all possible variants of the model. I therefore believe that there is merit in entertaining a different type of models that are more informal but that reveal new answers to old questions, that generate new questions and new predictions, and that point at new ways of influencing behavior. Propositional models of associative learning as I conceive of them belong to the second type. I see them as a class of (current and future) models that are defined by the core assumption that associative learning is mediated by the formation of propositions. Postponing the formalization of this core idea allows one to appreciate more fully the wide range of processes that contribute to learning in general and EC in particular. Some might argue that it is more appropriate to refer to these ideas as a theoretical perspective or framework rather than as a theoretical model. Because it is not clear to me what criteria "true" models should meet, nor whether there are many ideas in psychology that "truly" deserve this label, I will not take a definite stance on this issue. I do hope to show, however, that the ideas underlying propositional models of EC – when understood correctly – can foster progress in EC research.

Assumptions that Propositional Models Do and Do Not Make

Core Assumption

The class of propositional models of EC encompasses all current and future models which postulate that stimulus pairings can influence liking only after a proposition has been formed about the relation between the stimuli. [1] A proposition about a stimulus relation is an informational unit that is defined in terms of its informational content: it is a mental representation that contains information about the nature of the relation between stimuli (e.g., A *predicts* B, A *causes* B, A *co-occurs with* B, …). Because there are many different ways in which stimuli can be related, different propositions can be formed about the same stimulus pair. For instance, the same pairing of stimulus A with stimulus B can lead to the proposition that A *co-occurs with* B, that A *predicts* B, or that A *causes* B (De Houwer, 2009). Which propositions are formed depends not only on the spatio-temporal properties of the stimulus relation (when and where stimuli occur in space and time) but also on other factors such as

[1] In principle, it is also possible that the pairing of a neutral and a valenced stimulus leads to a proposition about the relation between the neutral stimulus and the evaluative response to the valenced stimulus (e.g., "when I see this stimulus, I always get a bad feeling"; see Gast & Rothermund, 2012). That is, the propositions that mediate EC might also involve information about evaluative responses. For reasons of simplicity, in this paper, I consider only propositions about stimulus relations. First, conceptually, it is sometimes difficult to make a distinction between what is a stimulus and what is a response. Second, theoretically, the assumptions and predictions of propositional models are most often unaffected by whether the mediating propositions involve information about evaluative responses.

the broader context (including instructions) and the background knowledge that people possess (Lagnado, Waldmann, Hagmayer, & Sloman, 2007). Many propositions encode more than mere spatio-temporal information (e.g., the proposition "A causes B" encodes also information about which stimulus has causal power). Nevertheless, it is important to note that propositions about stimulus relations can also encode only spatio-temporal information (e.g., A *co-occurs with* B) or only the fact that there is a relation (e.g., A *is somehow related to* B). All propositions, however, are statements about the world and therefore have a truth value in the philosophic sense. This means that each proposition has the potential to be true or untrue, even if its subjective or objective truth cannot be determined in actuality (e.g., even the statement "angels have wings" qualifies as a proposition). The fact that propositions have truth value allows for the operation of inferential processes by which truth value can be transferred or transformed from one proposition to another.

Propositions are fundamentally different from associations. Whereas propositions are defined in terms of their informational *content*, associations are representational *structures* that allow for activation to spread from one node to another. Although fundamentally different, propositions can be related to associations by looking at the informational content that associative structures can encode. On the one hand, a single association that links two nodes is very limited in its capacity to encode relational information (e.g., to encode the difference between "A *causes* B" and "A *predicts* B"; Hummel & Holyoak, 2003; Gentner, 2016). Therefore, associative models according to which EC is mediated by the formation of simple associations are incompatible with propositional models: they cannot capture the relational information nor the truth value that define propositions. On the other hand, some have argued that more complex associative structures (e.g., parallel distributed networks of associations) can capture complex relational information (e.g., Gawronski & Bodenhausen, 2006). If it is indeed the case that these networks can encode propositional content (i.e., statements with a truth value that specify relational information) then these complex associative network models should not be contrasted with propositional models; in fact, they would qualify as instances of propositional models (De Houwer, 2014a). [2]

Some have argued that because associative structures could *in principle* encode propositional content, the debate between association formation models and propositional models of EC is therefore without substance (e.g., Gawronski, Balas, & Hu, 2016). I disagree. Most current association formation models involve simple associative links that cannot encode propositional content (see Hofmann et al., 2010, for a review). Even the models that postulate the existence of more complex associative networks only hand-wave to the idea that those networks could encode propositions. In actuality, there is no associative network model that even comes close to simulating effects of relational information (e.g., Hummel & Holyoak, 2003) and there are good reasons for why this is the case (Hummel, 2010). This is probably why during the long reign of association formation models, proponents of those models rarely, if ever, initiated research on the role of relational information in associative learning (including EC): their models have nothing to say about this. Hence, until association formation models are developed that can deal in a satisfactory manner with the effects of relational information, propositional models should continue to be contrasted with association formation models.

Other Assumptions

As I noted above, propositional models of EC are defined by the assumption that stimulus pairings result in a change in liking only if a proposition is formed about the relation

[2] Although these type of associative network theories of propositional learning can have the benefit of being more formalized, they have the downside of being committed to a particular representational structure. Propositional models that are not committed to a representational structure have more degrees of freedom and thus have more flexibility and scope. Still, it seems easier to reach agreement about representational content and about the environmental events that influence this content than agreement on the representational structures in which this content is embedded (De Houwer & Moors, 2015). Too much focus on representational structure could thus be counterproductive.

between the stimuli. Different propositional models might, however, differ with regard to the assumptions they make about the way in which propositions are formed, the precise content of the mediating propositions, as well as the way in which propositions influence evaluative behavior. In this section, I discuss specific ideas that have been put forward about these additional components of propositional models.

Formation of propositions: From pairings to propositions about stimulus relations. It has been argued that the processes by which stimulus pairings lead to the formation of propositions are very similar to the processes by which humans solve problems (De Houwer, 2009; Mitchell et al., 2009). Living organisms are confronted with an environment in which many stimuli (co-)vary in complex ways. Successfully navigating through such an environment requires the detection of certain but not all patterns of covariation. Responding to all covariation would lead to chaotic behavior. Instead, organisms need to detect those covariations that can help them optimize their behavior. This is why the task of adapting to covariation in the environment can be seen as a problem and why learning processes might have much in common with those underlying problem solving. In the remainder of this section, I highlight two commonalities that have important implications for research on EC.

First, just like other forms of problem solving, the formation of propositions about stimulus relations does not result from a mere passive registration of events in the world but from constructive processes that can deploy all the channels of information that organisms have at their disposal. This includes information that is available in memory, that is received from others via instructions, or that can be inferred from the observation of others or from directed interventions in the world. Hence, EC is not an inevitable consequence of stimulus pairings; it arises only when those pairings are constructed in a specific manner. Moreover, because all of these channels produce propositional knowledge, information gained from different channels can easily be combined and used to infer new propositions.

Second, because problem solving is usually considered to be a non-automatic process, proponents of propositional models have typically also characterized the processes underlying proposition formation as non-automatic. More specifically, those processes are assumed to involve awareness (i.e., of the propositions that are produced) [3], time (i.e., the processes are slow), effort (i.e., they depend on mental resources), and the goal to learn (i.e., they depend on intention). Interestingly, although the evidence is not entirely conclusive, there is strong support for these ideas in the context of EC (e.g., Hofmann et al., 2010, and Corneille & Stahl, in press, for reviews). Note, however, that some instances of problem solving do seem to have at least some features of automaticity. For instance, solutions to problems can sometimes pop up quickly and almost effortlessly into one's head. But even those instances of problem solving appear to be non-automatic in some respects (e.g., depend on awareness of the solution and the intention to solve the problem; see Moors, 2016, for an insightful discussion of why seemingly non-automatic processes can sometimes also have features of automaticity). Regardless of the existence or nature of automatic problem solving, from the perspective of propositional models, much can be gained by exploring the links between problem solving and EC. [4]

The relational content of propositions. Although propositions can encode different types of relations, proponents of propositional models have until now said little about the variables that determine the relational content of propositions. One obvious factor is the presence of instructions about stimulus relations. For instance, when non-words and words

[3] There is no reason to assume that the formation of propositions about stimulus relations requires awareness of the processes by which propositions are formed but one could argue that it requires awareness of the input (i.e., the stimuli that are paired) and the output of those processes (i.e., a proposition about how the stimuli are related).

[4] Some might argue that automatic instances of problem solving (and EC) are mediated by associative processes. Although it is difficult to exclude this possibility on an a priori basis, others have convincingly argued that automatic problem solving relies on automatic inferences that are performed on propositional representations (e.g., Sanborn & Chater, 2016).

are paired on a computer screen, some participants could be told that the non-word is a synonym of the word it is paired with whereas others could be told that the two are antonyms (e.g., Zanon, De Houwer, Gast, & Smith, 2014). Also non-verbal cues can influence the content of propositions if those cues have previously been linked with specific types of relations (Hughes, 2012; Hughes et al., 2018). Finally, the nature of the stimuli is likely to constrain the way in which they are related. For instance, when pairing a word and a non-word, the word might be interpreted as conveying the meaning of the non-word (especially when the experiment is described as a study on learning new words) whereas the same word might be interpreted as a personality trait when it is paired with a picture of an unknown person (especially when the experiment is said to be a study on person perception). Such effects arise because participants bring with them a wide range of propositions that were formed before the start of the experiment and that they deploy in order to make sense of the experimental situation. Making accurate and precise predictions regarding the relational content of propositions that result from pairings is difficult because there is such a diverse range of pre-existing knowledge that participants can bring to bear when confronted with stimulus pairings and so many contextual cues that could influence which knowledge they bring to bear. Nevertheless, propositional models enrich the literature on EC by highlighting the role of relational content in EC, as well as the impact that pre-existing knowledge and contextual factors can have by influencing the relational content of propositions.

Proponents of propositional models of EC also said little about whether and how differences in relational content lead to differences in the magnitude and direction of the changes in liking. This seems to imply that, in principle, any proposition that relates a neutral stimulus to a valenced stimulus could result in a change in liking. In an earlier paper (De Houwer, 2009), I did note that, compared to other types of associative learning, EC might depend more on propositions about stimulus co-occurrences (A *co-occurs with* B) than on propositions about the predictive relation between stimuli (A *predicts* B). This proposal was based on the idea that evaluative responses are not emitted in order to prepare for the upcoming presentation of a stimulus, unlike to what is the case for many other responses that are studied in conditioning research (e.g., skin conductance responses). It is also in line with the observation that EC is relatively insensitive to manipulations that influence the predictive relation between stimuli (e.g., extinction). However, little research has been directed at verifying this proposal. In a recent paper, Hughes, Ye, Van Dessel, and De Houwer (in press) pointed out that different types of propositions could lead to different changes in liking depending on what attributions those propositions allow for. For instance, whereas the proposition that A *causes* B implies that A is responsible for the impact of B, the proposition that A *predicts* B does not allow one to attribute the presence of B to the presence of A (Heider, 1958). In support of the idea that attributional processes can be important in EC, Hughes et al. (in press) observed that the impact of the evaluative properties of B on the liking of A was bigger when the relation between A and B was said to be causal than when it was said to be merely predictive.

Impact of propositions on behavior: From propositions about stimulus relations to changes in liking. Because propositions have a truth value and therefore *allow* for the operation of non-automatic, rational inferential processes, it is often assumed that propositions can influence behavior (1) *only* via inferential processes and therefore (2) *only* in a non-automatic, rational manner. In this section, I point out that propositions can, in principle, influence liking not only via non-automatic, rational inferential processes but also via (1) automatic inferential processes and (2) automatic similarity-based retrieval processes.

Inferential processes are processes via which propositions are derived or validated on the basis of other propositions. They can operate in non-automatic ways, that is, only when awareness, time, effort, and intention are involved and in ways that meet rational normative standards as put forward by philosophers. It might well be that some instances of EC involve non-automatic inferential processes that lead to normatively correct conclusions. However, even non-automatic inferential processes can lead to irrational conclusions and thus irrational behavior (e.g., when starting from incorrect premises or following normatively incorrect inference rules). Moreover, it is important to realize that inferential processes can also operate automatically to some degree. In fact, predictive coding models of human cognition (e.g., Metzinger & Wiese, 2017) are built on the assumption that human beings constantly make inferences automatically. [5] The effectiveness of popular behavioral techniques such as nudging (e.g., Thaler & Sunstein, 2008) also suggest that humans often base their decisions and behavior on quick-and-dirty reasoning. Drawing on these ideas, Van Dessel, Hughes, and De Houwer (2018) have recently specified a model of how (automatic) inferential processes might underlie the effects of (approach-avoid) actions on liking. When translating their ideas to the context of EC, the model implies that a proposition about a stimulus pairing (e.g., "A co-occurs with B") can be combined with pre-existing propositions (e.g., that similar things tend to co-occur). This sets the stage for the evaluative inference that A (probably) has the same valence as B. In line with predictive coding models, Van Dessel et al. assume that these inferential processes can have features of automaticity. More specifically, both the validation of propositions (whether they are true or untrue) and the derivation of new propositions about stimulus valence can occur with little awareness of the underlying process, quickly, with little effort, or unintentionally. [6]

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[5] An anonymous reviewer noted that predictive coding models are closely related to associative models in which the formation of associations depends on prediction error (e.g., Rescorla & Wagner, 1972). However, this does not exclude the idea that predictive coding (and EC) can involve automatic inferences. Moreover, it has been argued that so-called "associative" prediction error models are nothing more than mathematical formalizations of inferential propositional processes that are not inherently associative in nature (i.e., they are situated at Marr's computational level rather than algorithmic level of explanation; see Cheng, 1997, p. 370) or even incompatible with the spirit of associative models (Jozefowiez, in press).

[6] It would be interesting to compare the automaticity features of the problem solving processes via which propositions about novel stimulus relations are formed and the inferential processes via which those propositions influence evaluative responses and other behavior. It is likely that these processes have much in common. In fact, problem solving might necessarily involve inferences. Nevertheless, to avoid chaotic behavior,

It is important to realize that propositions might also be operated upon by similarity-based retrieval mechanisms. This possibility is often ignored because of a tendency to confound operating principles and mental representations (see Moors, 2014, for an excellent discussion). There is no reason why the content of representations (i.e., whether they contain relational information) would determine whether those representations can be retrieved from memory on the basis of similarity with the current environment. [7] In fact, one could easily imagine episodic memory models that are compatible with propositional models of EC (e.g., De Houwer, 1998; Stahl & Heycke, 2016). Episodic models (e.g., Hintzman, 1986; Medin & Schaffer, 1978; Schmidt, De Houwer, & Rothermund, 2016) postulate that each event is encoded in memory as a separate trace and that memory traces are activated on the basis of the similarity between the information stored in those memory traces and the subjective experience of the current situation. Because memory traces capture the subjective experience of each situation, they are likely to contain propositions, that is, information about the ways in which stimuli and responses are related in that situation (Schmidt et al., 2016). Hence, episodic models seem well suited to model how liking can be influenced by the similarity-based retrieval of propositions.

Note, however, that episodic memory models currently do not take into account the

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it could be advantageous for living organisms to put more restrictions on the detection of novel spatio-temporal relations (of which there are an infinite number in the environment) than on the combination of already available knowledge (which concerns only a subset of all information in the environment) especially when taking into account that inferential reasoning during retrieval can easily be shaped via reinforcement. This is why I tend to emphasize the non-automaticity of the formation of propositions about stimulus relations and the automaticity of inferential retrieval processes via which already available propositions influence liking and other behavior, being well aware of the fact that all processes possess a mix of features of (non-)automaticity that can vary over contexts (see Moors, 2016, for more details). Most importantly, I assume that, whereas the formation of a proposition requires awareness of its content, the retrieval of a proposition could well be achieved and influence liking in the absence of awareness of its content.

[7] The Associative and Propositional Evaluation (APE) model of Gawronski and Bodenhausen (2006, 2014) is built on the distinction between two operating principles: similarity based-retrieval and validation. Although Gawronski and Bodenhausen correctly state that validation requires propositional representations, they incorrectly assume that similarity-based retrieval requires associative representations. This incorrect assumption is probably based on the idea that (1) similarity-based retrieval can be realized only via spreading of activation and (2) spreading of activation requires associative representations. If one allows for the possibility that similarity-based retrieval can also involve propositional representations, however, there is little reason left to insist on the presence of associative representations next to propositional representations within the APE model.

impact of (automatic and non-automatic) inferential processes on EC and are therefore unlikely to capture the full complexity of the mechanisms underlying EC. Also note that allowing for similarity-based retrieval leaves open the question of which propositions can influence liking via *mere* similarity-based retrieval. Once a proposition has been retrieved from memory on the basis of similarity with the current environment, that proposition could influence liking either indirectly (by influencing inferential processes) or directly (without any involvement of inferential processes). It seems reasonable to assume that, once a proposition has been formed about the valence of a stimulus (e.g., "A is good"), the mere presentation of A suffices to retrieve this evaluative proposition in a similarity-based manner, which in turn would suffice to influence evaluative responding to that stimulus without the involvement of inferential processes (but see Van Dessel et al., 2018, for the idea that inferential processes might also be involved in the impact of evaluative propositions on evaluative responses). On the other hand, similarity-based retrieval of propositions that relate a stimulus not with a summary valence (e.g., "A is good") but with a valenced event (e.g., "A co-occurred with something good") might have an impact on liking only after this proposition is combined with other propositions (e.g., "things that co-occur with good things tend to be good") via (automatic) inferential processes. In sum, whereas it seems difficult to deny any role for similarity-based retrieval in propositional models of EC, different models could incorporate different assumptions about whether and when similarity-based retrieval of propositions is sufficient to influence liking.

One might argue that permitting similarity-based retrieval of propositions is undesirable for several reasons. First, it renders the class of propositional models virtually immune to falsification. In fact, a propositional model in which changes in liking can result from both (automatic) inferential processes and direct effects of similarity-based retrieval is effectively a dual-process model in that it incorporates two mechanisms via which propositions can lead to EC effects. It thus falls prey to the same criticisms that have been directed at dual-process models in general (e.g., the fact that these models often lack clear assumptions about how the various processes interact; Mitchell et al., 2009; Moors, 2014). Second, allowing for similarity-based retrieval reduces the difference between propositional models and associative models (which also allow for similarity-based retrieval). It therefore removes some of the fuel for the debate between these two classes of models that has fired up EC research during the past decade.

In response to these concerns, it is important to point out that they relate only to propositional models that allow for direct effects of similarity-based retrieval of propositions. Propositional models that postulate only indirect effects of similarity-based retrieval would not qualify as dual-process retrieval models in the strict sense (i.e., all instances of EC would be mediated by inferential processes) and would be as fundamentally different form associative models than propositional models that do not incorporate similarity-based retrieval. In fact, for reasons of parsimony, there is merit in seeing how far one can get with single-process inferential models of EC according to which propositions about stimulus relations can influence liking only via inferential processes (e.g., a variant of the model put forward by Van Dessel et al., 2018).

Nevertheless, there is little point in dismissing offhand the possibility of direct effects of similarity-based retrieval of propositions simply because it makes it more difficult to falsify or differentiate between theoretical models. As noted in the introduction, there are downsides to focusing too much on falsification. Instead, theoretical models can be thought of as tools that help organize existing knowledge about the moderators of phenomena (heuristic value) and discover new moderators (predictive value) with the aim of increasing our capacity to influence those phenomena and the real life behaviors that are instances of those phenomena. There is merit in acknowledging that EC might be mediated by both inferential and similarity-based retrieval processes because it raises interesting new questions about the conditions under which both types of processes result in EC effects. Even propositional models that allow for both these processes would still differ from associative models in so many ways (e.g., the non-automatic formation of propositions, the impact or relational content, instances of EC that are mediated by inferential processes) that there is enough fuel left to continue the debate between both types of models.

Putting Things Together

The Integrated Propositional Model of EC

Based on the considerations that were discussed above, it is possible to assemble one version of a propositional model of EC that I will refer to as the Integrated Propositional Model (IPM). It incorporates many of the ideas that were put forward in the first part of this paper and in earlier papers (e.g., De Houwer, 2009; Mitchell et al., 2009) but is unique in that it integrates in a more explicit manner assumptions about the formation, storage, and retrieval of propositions and thus covers the overarching chain of processes via which stimulus pairings can result in changes of liking (De Houwer & Moors, 2015). [8] In doing so, it incorporates a number of choices that differentiate it from other possible propositional models of EC. Like all other possible propositional models of learning, however, it starts from the core idea that stimulus pairings can influence liking only if a representation is formed that contains information about the nature of the relation between stimuli. The formation of these propositions is assumed to be based on the same, largely non-automatic processes that underlie problem solving. Hence, propositions about stimulus relations can be formed not only on the basis of stimulus pairings, but also on the basis of instructions, observation, interventions, and inferential processes. The formation of propositions is thought

[8] This is a revision of the model that I presented at the EC expert meeting in Ghent (Belgium) on 20 December 2010.

to take place in working memory where input from external sources can be combined with input from long-term memory and other propositions that are already represented in working memory. Although the content of working memory is typically accessible to conscious awareness, working memory processes themselves can vary in terms of automaticity features (e.g., slow and effortful versus “quick-and-dirty” inferential reasoning). Once a proposition has been formed in working memory, this information can be stored in long-term memory. In line with the model of approach-avoidance effects that was put forward by Van Dessel et al. (2018), the IPM postulates that EC requires not only the formation of propositions about stimulus relations (e.g., “A co-occurs with B”) but also evaluative stimulus propositions (i.e., propositions about the evaluative features of stimuli; e.g., “A is good”). Evaluative responses to stimuli only reflect the content of evaluative propositions in working memory. Hence, propositions that relate stimuli to other objects (e.g., “A causes something good”, “A co-occurs with something good”) can impact on liking only via (automatic or non-automatic) inferential processes that produce evaluative propositions (e.g., “A is good”; see Van Dessel et al., 2018, for more details). [9] Once an evaluative proposition has been formed and stored in memory, additional inferential processes can be side-stepped by similarity-based retrieval of

[9] As noted above, other propositional models might allow for direct effects of propositions about stimulus relations (i.e., without requiring inferential processes via which evaluative propositions are formed). The IPM does not allow this route for reasons of parsimony. If it would have permitted this route, additional assumptions would have been needed about when which route operates (see De Houwer, 2014b, for similar arguments in favor of single-learning-process propositional models as compared to dual-learning-process models). Unlike other models (e.g., Van Dessel et al., 2018), the IPM does permit an impact of evaluative propositions on evaluative responses that is not based on inferences. This choice is based on the idea that one would need to stretch the concept of an inference in order to conceive of ways in which concrete evaluative responses can be inferred from evaluative propositions. For instance, it is difficult to see how increased activity of the corrugator muscle can be inferred from the proposition that something is bad in our definition of an inference as the process of reaching a conclusion on the basis of premises. One could, however, define an inference more broadly, as the probabilistic activation (or prediction) of information on the basis of other information (Van Dessel et al., 2018) such that muscle activity might be seen as an (active) inference on the basis of prior information about one’s typical response to negative stimuli (see also Friston, 2010). I believe, however, that the question of how mental representations influence behavior is a complex one that is currently not addressed in a satisfactory manner by either propositional or associative models (see Bouton, 2016, pp. 187-190). Although the choices made in the IPM can thus be justified, I put more value in highlighting theoretical questions as potentially interesting than in opting on an a priori basis for one answer to those questions. Whereas the latter might promote falsification, the former is more likely to facilitate progress in understanding psychological phenomena.

evaluative propositions from long-term memory. Figure 1 provides a graphic illustration of the IPM.

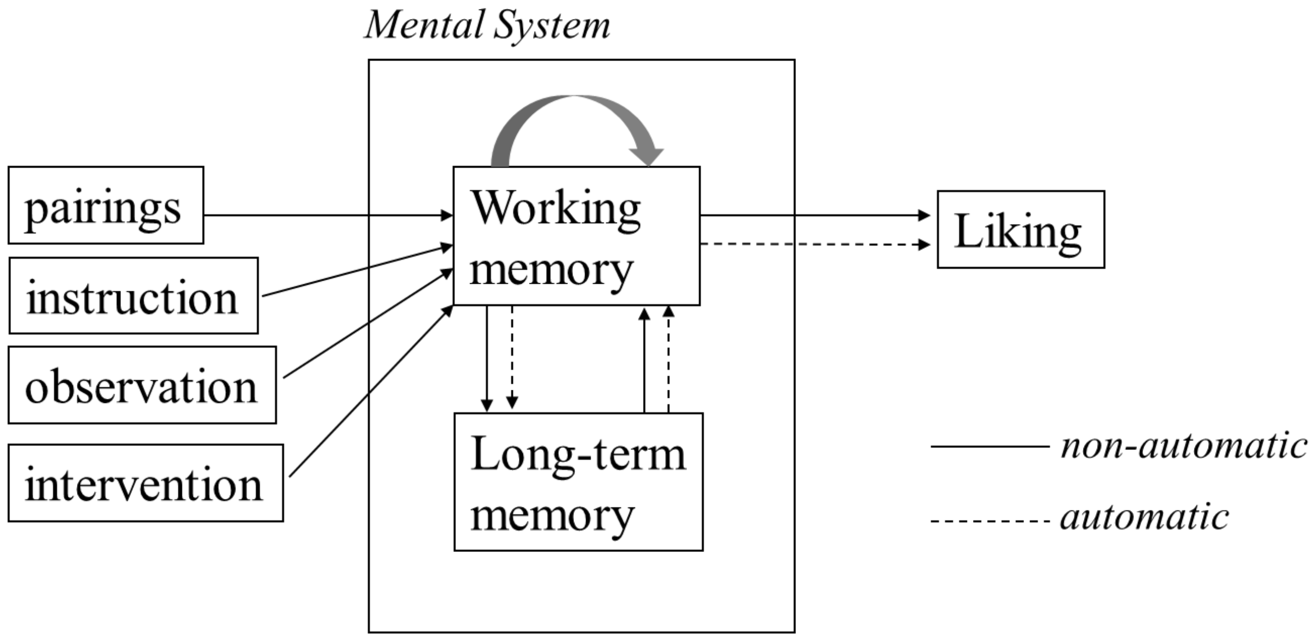

Figure 1. The Integrated Propositional Model. Pairings, instructions given by others, the observation of others, and the outcome of interventions in the world by the organism (jointly) lead to the formation of propositions about stimulus relations in working memory. New propositions can also be inferred from other currently entertained propositions (large grey arrow) as well as propositions that are retrieved from memory via automatic or non-automatic retrieval processes. Propositions are automatically stored in memory as episodic memory traces, although non-automatic processes such as rehearsal and elaboration can also influence memory storage. Evaluative propositions (propositions about evaluative stimulus properties) that are entertained in working memory can influence liking via both automatic and non-automatic processes.

Although it is impossible to discuss all details of the model within the confines of this article (see Van Dessel et al., 2018, for a highly similar model), I will try to make the model a bit more concrete by considering the case in which a neutral picture of an unknown person is repeatedly paired with a pleasant picture of beautiful landscape. These stimulus pairings can, under certain conditions (see Van Dessel et al., 2018), lead to the proposition that the picture of the person and the picture of the landscape co-occur. In line with the ideas of Van Dessel et al. (2018), this proposition can be combined with the pre-existing proposition in memory that stimuli that co-occur in space and time typically also have other things in common, including their valence. As a result, participants can infer that the person has the same valence as the landscape and thus construct the evaluative proposition that the person is good. Such inferences can be made in a careful, deliberative manner (e.g., when participants have ample time and resources to form an opinion of the novel person and have nothing else to go on other than the fact that the person and landscape co-occur) but might also be made in a more automatic manner (e.g., when participants reason in a "quick-and-dirty" manner because of a lack of time, resources, or motivation; see Van Dessel et al., 2018, for more details). Evaluative propositions cannot only be constructed on the spot via inferential processes but can also be retrieved from long-term memory via similarity-based processes. Liking will be based on the evaluative propositions that are entertained in working-memory (see Footnote 9).

Heuristic and Predictive Value of the IPM

Impact of Relational Information. The IPM, as well as all other propositional models, predicts that EC can be influenced by variables that entail information about the nature of the relation between stimuli (e.g., instructions; contextual cues). This prediction lies at the core of all propositional models of EC because the only way to explain the impact of relational information on EC is to assume that EC is mediated by representations that specify the nature of the stimulus relation. In recent years, many studies have shown that relational information can influence EC effects (e.g., Moran & Bar-Anan, 2013; Hu, Gawronski, & Balas, 2017; Zanon et al., 2014), thus supporting the idea that propositional representations do contribute to EC effects.

It is important to note, however, that the IPM and other propositional models are not necessarily contradicted by a lack of impact of relational information (e.g., a less than maximal impact of the instruction that stimuli are antonyms; Zanon et al., 2014). On the one hand, there are theoretically uninteresting reasons such as a lack of power or a partially unsuccessful manipulation of relational information. On the other hand, as noted already by De Houwer (2009), it is also important to remember that a person can simultaneously entertain several propositions about a stimulus relation (e.g., “A *co-occurs with* B”, “A *is an antonym of* B”; e.g., Zanon et al., 2014). Likewise, different persons can form different propositions after experiences of the same pairings. Hence, a less than maximal impact of relational information on EC could result from the fact that the observed changes in liking are (to some extent) mediated by propositions that do not encode certain types of relational information (e.g. “A *co-occurs with* B”). Note that for the same reasons, evidence for a unique impact of actual stimulus co-occurrences independent of the impact of relational information (see Moran, Bar-Anan, & Nosek, 2016), would also not refute the IPM or other propositional models. Stimulus co-occurrences can lead to the proposition that the stimuli co-occur, which might influence liking on top of the impact of other propositions that do specify the nature of the relation in more detail (e.g., A *is opposite to* B). In other words, multiple propositions could simultaneously bias EC effects. These assumptions do not make the IPM unfalsifiable but increase its power to make novel, testable predictions. For instance, variables that selectively influence the evaluative implications of certain propositions (e.g., that undermine the assumption that co-occurring stimuli have the same valence; see Van Dessel et al., 2018) should have selective effects on EC (e.g., increase the probability of reversed EC effects when stimuli are said to be opposite).

Impact of Instructions, Observation, Interventions, and Inferences. The IPM postulates that the formation of propositions has much in common with problem solving. The IPM therefore predicts that (1) even in the absence of pairings, other sources of information might also lead to changes in liking, (2) those changes in liking resemble EC to the extent that the other sources convey the same information as actual stimulus pairings, and (3) the impact of one source of information can depend heavily on the information provided via other sources.

Regarding the first prediction, it has now been established that mere instructions about stimulus pairings (e.g., “A will be paired with B”) do indeed result in changes in liking (e.g., Gast & De Houwer, 2013; Hütter & De Houwer, 2017). Second, there are many similarities between EC and the effects of instructions about stimulus pairings. Just like actual stimulus pairings, pairing-instructions have an impact not only on explicit but also implicit (i.e., automatic) evaluations as captured by tasks such as the Implicit Association Test (IAT; e.g., Gast & De Houwer, 2013). Likewise, EC studies on extinction and contingency suggest that co-occurrences of stimuli have a bigger impact than stimuli presented on their own, irrespective of whether those events are experienced or merely instructed (e.g., Gast & De Houwer, 2013). Moreover, studies by Kurdi and Banaji (2017) suggest that pairing-instructions and actual pairings produce the same magnitude of changes in liking. In fact, in those studies, combining instructions about stimulus pairings with actual stimulus pairings did not result in a stronger effect than the instructions alone. From the perspective of the IPM, these findings are to be expected when instructions provide the same information about stimulus relations as experiencing actual stimulus pairings. Nevertheless, the IPM does allow for dissociations between the effects of different sources of information simply because the content of the information provided by each source can differ. For instance, the actual experience of events is typically richer than what can be expressed in words. One should, however, be able to reduce these differences by super-charging the instructions with information that is otherwise uniquely available in experience (e.g., by describing the stimuli more vividly or asking participants to engage in mental imagery).

With regard to the third prediction (interactions between different sources of information), research on the impact of verbal relational information on EC (e.g., Moran & Bar-Anan, 2013; Zanon et al., 2014) already shows that verbal instructions can moderate the impact of stimulus pairings on liking. In a similar vein, a study reported by Gast and De Houwer (2013, Experiment 2b) demonstrates that changes in liking that are produced by *actual pairings* can be reduced by giving counterconditioning *instructions* (i.e., telling participants that the stimulus that was previously paired with a positive stimulus will now be paired with a negative stimulus and vice versa). Although much more research is needed on interactions between the effects of stimulus pairings and the effects of other sources of information on liking, the results of Gast and De Houwer thus suggest that these interactions can be very powerful.

EC can have features of non-automaticity. The assumption that the formation of propositions is similar to problem solving has implications not only for the type of events that influence changes in liking (pairings, instructions, …) but also for the conditions under which stimulus pairings influence liking. More specifically, it implies that most instances of EC occur only after people become aware of the stimulus pairings, when people have ample time and resources to process information, and when they have the goal to learn. As noted above, there is strong evidence to support these assumptions (e.g., Hofmann et al., 2010, and Corneille & Stahl, in press, for reviews).

EC can have features of automaticity. Although the IPM implies that most instances of EC have features of non-automaticity, it also allows for the possibility that some instances of EC have features of automaticity. First of all, just like problem solving can sometimes be fast and effortless, propositions about stimulus relations might sometimes be formed quickly and with little effort. According to the IPM, however, EC can arise only after a conscious proposition of the stimulus relation has been formed. Second, once such a proposition has been formed, it can influence liking automatically via automatic inferential processes that result in the formation of evaluative propositions. Evaluative propositions that have been stored in long-term memory can influence liking also directly via similarity-based retrieval.

Based on the latter two assumptions, the IPM predicts that stimulus pairings, instructions about stimulus pairings, and instructions about evaluative stimulus properties can influence implicit evaluations. It also allows the IPM to account for instances of EC in which participants no longer consciously remember propositions about stimulus pairings and, relatedly, memory-independent EC effects as captured by multinomial processing tree models (see Hütter & De Houwer, 2017, for more details). Finally, because propositions can have automatic effects on liking, it is possible that some EC effects are difficult to control (Gawronski, Balas, & Creighton, 2014). It is important to note that all of these predictions simply follow from what is known about inferential reasoning and memory retrieval in general. Although the IPM does not contain a fully developed theory of inferential reasoning or memory, it implies that the properties of inferential reasoning and memory retrieval in general will apply also to EC. Hence, these are not post-hoc assumptions. Moreover, they provide the basis for generating new predictions. For instance, the IPM predicts that one should be able to find evidence for the involvement of propositional representations or inferential processes in instances of automatic EC. As noted above, this prediction can be tested by manipulating variables that entail relational information (e.g., Zanon et al., 2014), by examining whether mere instructions about stimulus pairings lead to the same automatic effects as actual pairings (see Hütter & De Houwer, 2017, for an example of this approach), or by testing whether variables that moderate the output of inferential processes also moderate EC (e.g., a person’s assumptions about whether stimuli that co-occur have the same valence; see Van Dessel et al., 2018). This again illustrates the predictive value of the IPM and the way it differs from other models of EC.

Dissociations between different instances of EC. Because different instances of EC can involve (a) different ways of forming propositions, (b) propositions about different aspects of a stimulus relation, and (c) different retrieval processes, the IPM predicts that dissociations can be found between different instances of EC. Above, I already hinted at the fact that different instances of EC might be differentially sensitive to relational information, depending on which propositions mediate EC (e.g., A *is somehow related* to B vs A *is a synonym of* B). Dissociations between instances of EC can also arise because they involve different retrieval processes. Consider instances of conditioned changes in implicit (automatic) liking (e.g., IAT scores). Within the IPM, these changes are mediated by automatic retrieval processes that are difficult to control. Hence, stimulus pairings can influence implicit liking even when participants have the intention to ignore them. Changes in explicit liking, on the other hand, are often based on non-automatic inferential processes (although they could sometimes be based also on automatic processes, as is the case when people rely on their gut feelings to determine their conscious opinions; Gawronski et al., 2016). Hence, the IPM is compatible with the observation that efforts to control EC have a bigger impact on explicit than on implicit liking (e.g., Gawronski et al., 2014). Although other models can also account for these results (e.g., Gawronski & Bodenhausen, 2006), again note that the IPM uniquely predicts that dissociations like these would arise even if the (implicit and explicit) changes in liking are based only on instructions in the absence of any stimulus pairings (see Van Dessel, De Houwer, Gast, Smith, & De Schryver, 2016, for related evidence in the context of approach-avoid learning research). This again illustrates the predictive value of the IPM.

Concluding Thoughts about the Limitations and Strengths of Propositional Models

Despite my efforts to clarify some of the assumptions of propositional models of EC in general and the IPM specifically, it will remain difficult if not impossible to refute these models. Consider the core assumption that EC is mediated by the formation of propositions about stimulus relations. It is likely that any empirical finding that questions this core assumption can be accommodated by adding or changing assumptions about the content of the mediating propositions or the processes that create and operate on those representations (De Houwer, Gawronski, & Barnes-Holmes, 2013). As I noted in the introduction, this problem is not unique to the class of propositional models but applies also to the class of association formation models (Miller & Escobar, 2001) and other classes of cognitive theories (Barsalou, 1990). Also individual association formation models are often difficult to disprove because researchers tend to rescue their pet model from falsification by changing it in a post-hoc manner. The difficulty to refute models should, however, not stop us from using them. Even when they cannot be refuted, they can still allow researchers to conceptualize existing empirical knowledge (i.e., they have heuristic value) or to formulate new predictions and thus discover new empirical facts (i.e., they have predictive value). There can be little doubt that propositional models of EC have considerable heuristic and predictive value (e.g., Corneille & Stahl, in press; Hofmann et al., 2010).

Despite their proven predictive value, the capacity of propositional models to specify exact predictions is still constrained by a lack of detail. Without specific assumptions about how propositions are formed, the variables that determine the relational content of the propositions, the link between relational content and changes in liking, the nature of inferential and similarity-based retrieval processes, and the interactions between these factors, it will remain difficult to generate specific predictions for specific situations. Having said this, the current lack of detail is understandable in light of the complexity and multitude of the processes that, according to propositional models, are involved in EC. A fully detailed propositional model of EC would encompass a detailed model of problem solving, attribution, relational processing, memory retrieval, inferences, and liking. In other words, it would require an almost perfect understanding of human cognition and behavior. [10]

[10] The conclusion that EC depends on all these processes might be disconcerting for those who hoped to find a simple, non-cognitive learning mechanism underlying EC. They might even wonder whether there is any reason for focusing on EC if the processes underlying it are essentially the same as those involved in other well-known phenomena such as persuasion. For me, the true merit of EC research lies in the unique source of liking that it

Nevertheless, by highlighting the wide range of processes that are important for EC, propositional models orient EC researchers toward the existing literature on these different processes (also see Boddez, De Houwer, & Beckers, 2017). Propositional models therefore entail the promise that by learning more about these processes, we can learn more about EC (and vice versa). As such, they reveal potential links between EC and many other psychological phenomena that involve similar processes. It is this orienting function of propositional models that might well turn out to be their main strength.

focusses on: spatio-temporal pairings of events. Although the mechanisms via which pairings and persuasive messages influence liking might be fundamentally the same, the difference in the events that set these mechanisms in motion could have important theoretical and practical implications (see De Houwer & Hughes, 2016, for a more detailed discussion). To further our understanding of how our likes and dislikes come about, these complexities should be embraced rather than discounted.

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