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An attribute-based approach towards nanotechnology attitude formation

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Abstract: This study presents a review of existing literature regarding attitude formation and integrates it into a model of attitude formation by means of attributes, applied to the case of nanotechnology. People may form attitudes about novel objects by relating them to objects with similar attributes, even if the entire object is largely unknown. Utilizing analogies or associations formed by mere exposure allows for connections between objects and their appraised attributes to be made. This allows for valence transfer from one object to another and thus evaluations are created by utilizing existing knowledge and associations. Repeated evaluation and exposure strengthens the connections upon which the attitudes are formed and may eventually lead to an automated response. For nanotechnology, the comparisons and associations that people make can determine whether public attitudes become positive or negative. Over time, these attitudes will become more stable and increasingly resistant to change as novelty wears off.

Keywords: Attitude formation, nanotechnology, public acceptance, novel technologies, technology attributes, learning processes

1. *Introduction*

The development of technology has proven to be a cornerstone in the evolution of human society. For example, the initial discovery of agriculture is often accredited to have led to major societal consequences that influence us to this day, leading to a change from hunter-gatherer societies to settled ones, in turn forming the foundations of our modern, civilized society. Although this case is but one example, in reality there have been many technological developments with great impacts, ranging from the invention of the wheel in the Bronze Age and the printing press popularized during the Renaissance to more contemporary inventions such as refrigeration, radio and the Internet. Besides being highly impactful on society, these technologies were also considered novel and revolutionary in their time, and probably controversial as well.

Browsing to the current day, *nanotechnology* is often cited to become one of the next novel technologies that could lead to major scientific and societal breakthroughs (Balbus, Florini, Denison, & Walsh, 2006; Cameron, 2006) and can be considered as a prime example of the accelerated discovery, development and innovation of the current times. Predictions are that nanotechnology development will increase rapidly in the near future; indeed products on the market imbued with aspects of nanotechnology are already becoming increasingly more common (Zhou, 2013). Additionally, nanotechnology is stated to have an increasingly growing influence on our lives (Roco, Mirkin, & Hesam, 2011). Subsequently, many scholars in the field of consumer and societal response to nanotechnology seem to embrace a constructivist philosophy, emphasizing the role of society as a determinant to the development of the technology (see e.g. Roco & Bainbridge, 2005; Scheufele & Lewenstein, 2005; Yawson & Kuzma, 2010)

As an emerging technology, consumer acceptance and public attitudes are especially deemed important to the further development of nanotechnology as societal rejection is considered detrimental to development and further commercialization of the technology (Ronteltap, Fischer, & Tobi, 2011; Siegrist, 2008). Past experiences with similar issues of consumer acceptance have led to problems such as the current public rejection of genetically modified organisms and food due to a lack of knowledge and risk communications (Greehy, McCarthy, Henchion, Dillon, & McCarthy, 2011). The field of nanotechnology in particular is characterized by uncertainties related to health- and environmental hazards and exposure to nanoparticles (Roco et al., 2011; Warheit, Sayes, Reed, & Swain, 2008). As far as public opinion is concerned, there seem to be ample opportunities for the development of nanotechnology to learn from the transgressions of earlier technologies (Mehta, 2004). Considering the relative importance of these novel technologies for society, understanding their public acceptance or rejection seems like a worthwhile cause

Despite these previous concerns relating to public attitudes and acceptance, awareness and knowledge of nanotechnology among the public is still low. A survey conducted in the European Union showed that less than half of all the participants had heard of nanotechnology and only 25% talked and/or had looked up information about nanotechnology (Gaskell et al., 2010). Waldron, Spencer, and Batt (2006) found comparable results in the United States. However, even in absence of knowledge, consumers can still form attitudes about emerging technologies (Scheufele & Lewenstein, 2005; Slovic, 1987). This possibility of attitude construction in cases of absent or low knowledge indicates that at least some aspects of nanotechnology can be related to existing knowledge, which then can serve as a means to form an evaluation about unfamiliar objects. This view is coherent with findings of Fazio, Shook, and Eiser (2004), indicating that attitudes of known objects can be generalized towards novel objects which share similarities, and van Giesen, Fischer, van Dijk, and van Trijp (2014) who argue that attitude object cognitions in relation to unfamiliar objects can be constructed from their realistic context. This leads to the first question: *how are nanotechnology attitudes formed?*

Furthermore, the notion of nanotechnology is often accompanied with tensions or dichotomies, such as naturalness versus artificiality (Rozin, 2005; Siegrist, 2008), risks versus benefits (Fischer, van Dijk, de Jonge, Rowe, & Frewer, 2013; Stampfli, Siegrist, & Kastenholz, 2010), trust versus mistrust (Siegrist, 2008) and even relating to the 'transformation of human nature' (Cameron, 2006). These tensions contribute to the contested character of nanotechnology perceptions and form part of the range of attributes, or characteristics, that nanotechnology is perceived to possess. Attributes in this case are related to mainly intangible aspects of technologies (e.g. healthiness, innovativeness), which can function as 'cognitive nodes' upon which attitudes can be formed (van Overwalle & Siebler, 2005). This leads to the second major question, namely, *how are attributes of objects connected to attitude formation?*

Currently, there are streams of literature available on the acceptance and perceptions of nanotechnology attributes (and those of similar novel technologies), as well as literature on attitude formation towards novel objects. However, these streams have thus far not been sufficiently integrated. Therefore, this paper aims to contribute by combining both attitude formation and technology attributes into a coherent model. In addition to identifying which connections can be made between attributes and attitudes, this paper also draws upon learning theories to provide an explanation for how these connections come to exist.

1. Attitude formation

Defining attitudes

Attitudes can be viewed as object-association evaluations which can differ in strength and accessibility from memory (Fazio, 2007). They are therein viewed as forms of knowledge in relation to the attitude-object. However, this knowledge can be constructed in a multitude of ways; it is not limited to merely analytic and cognitive appraisals but can also include affective evaluations, past experiences and appraisal of the objects' attributes (Fazio, 2007; Zanna & Rempel, 1988). The ways in which the knowledge is constructed can affect the strength of the attitude. Specifically, it is possible to define the variance of this attitude strength as an attitude-nonattitude continuum. At the nonattitude end, there is no available evaluation of an individual towards the object, and thus there are no attitudes. Moving towards the other end of the continuum, attitudes are increasingly more available in memory and more strongly associated with the object being evaluated which leads to increasingly more automatic activation of the attitude (Fazio, 2007; Fazio, Sanbonmatsu, Powell, & Kardes, 1986).

Roads to attitudes

From this perspective of varying attitude strengths and knowledge, two major pathways of attitude formation can be deduced which are relevant for this paper. The first path can be considered as the direct route and consists of an immediate, direct relation between the object and the attitude, which is then valued either positively or negatively. In order for an attitude to be activated this way, the attitude must be stored in memory which must be accessible by the individual. Prior learning must have taken place to form the attitude, i.e. by means of prior evaluation of the object. In line with the reasoning of Fazio (2007), the attitude-object in this case will prompt the corresponding attitude in an automatic fashion and the object will be more strongly associated with the evaluation.

In reality, however, public knowledge of nanotechnology is considered low (Gaskell et al., 2010; C. Lee, Scheufele, & Lewenstein, 2005; Waldron et al., 2006). Therefore, it is unlikely that, among the majority of the public, attitudes related to nanotechnology are strongly formed since they are not readily accessible in memory and are less likely to be cued spontaneously. Rather, they are more likely to balance towards the nonattitude side of the spectrum; the individual's attitude is weakly formed or he/she has not formed an attitude towards the object. In the former case, the addition of new knowledge can significantly and quickly alter the way in which people perceive nanotechnology (Dudo, Choi, & Scheufele, 2010; Vandermoere, Blanchemanche, Bieberstein, Marette, & Roosen, 2011) and, by extent, has the ability to change their attitudes (Scheufele & Lewenstein, 2005). The addition of more knowledge can lead to stronger attitudes through the process of the object-association evaluation. These stronger attitudes have shown to result in more stable attitudes due to their accessibility in memory and being better predictions of behavior than weak attitudes (Bassili, 1996; Krosnick, 1989). Although strong attitudes are present in memory and are readily accessible, weak attitudes are more likely to be (re)constructed or elaborated upon due to the availability of additional knowledge, which may lead to them becoming strong attitudes. In the absence of any available attitude towards the object, the attitude will have to be constructed entirely when the individual is confronted with the object.

The need for attitude (re)construction leads to the second path of attitude formation considered in this paper. This route considers attitude formation as a process of evaluations or judgments of the objects' attributes. That is, instead of having a direct, automatic response towards the attitude-object, an individual is instead prompted to appraise the attributes of the object in order to value them and eventually form a judgment, leading to the construction of an attitude. As discussed above, this approach is more relevant to the current situation of nanotechnology due to the lack of strong pre-existing attitudes, instead leading to a need to (re)construct attitudes. The attributes of the attitude-object have often been related to the construction of attributes and this approach then can be considered consistent with several previous approaches towards attitude formation. The classical approach of the expectancy-value model by Fishbein and Azjen (1975) posits that attitudes are normally formed based on beliefs related to the object. These beliefs, in turn, are generally formed by associating certain attributes to the object which are then valued positively or negatively and are eventually linked to desirable or undesirable consequences based on the attributes' valence (Azjen, 1991). Connectionist approaches present a model which utilizes these attributes to form attitudes, showing that object attributes can also be integrated with such approaches focusing on learning processes (van Overwalle & Siebler, 2005). This connectionist approach considers individual attributes as 'cognitive nodes', varying in strength, resulting in evaluations valued positively or negatively. The variance in strength is defined as a difference in the weighting of the object-attribute connections, based on previous experiences (direct or indirect) with the attribute and the number of occurrences (van Overwalle & Siebler, 2005). Fazio (2007) states that attitudes may be constructed through deliberation of individual attributes possessed by the attitude-object, dependent on the individuals' motivations and capabilities to form attribute evaluations.

In summary, previous attitude research has already discerned the role of the object attributes in attitude formation. The second (indirect) route thus considers the attitude formation through evaluation of the objects' individual attributes, as opposed to a direct, automatic response, i.e. the first route. An overview of both considered routes is shown in Figure 1. The direct route will likely not yet have much merit in the current situation of nanotechnology, mainly due to a lack of pre-existing evaluations, inability to automatically evoke the attitude and so forth. To understand novel attitude formation e.g. in this case of nanotechnology, an attribute-based approach seems promising. However, in order to further investigate such attribute-attitude relation, it is important to first consider the relation between the object and the attributes, to be discussed in the following chapter.

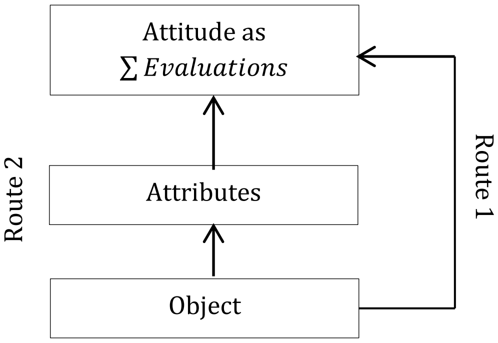

Figure 1: *Representation of direct object-attitude formation and an attribute-based approach of attitude formation.*

2. *Technology attributes in attitude formation*

Attributes within the model

An object can be viewed as a collection of attributes or features, which can be associated with the object through general knowledge of the world. In this perspective, attributes can be considered in a broad definition. They include not only the concrete properties (e.g. height, color, etc.) but also abstract properties such as quality and complexity (Tversky, 1977). In the case of nanotechnology, the technology itself is considered to be the object and concrete attributes may consist of the material size and the types of material used, while abstract properties may include (perceived) innovativeness, simplicity, user and social compatibility, usefulness, and so forth (see e.g. C. Chen, Chang, & Hung, 2011; Rogers, 1995). When considering attributes as a way to form attitudes, attention should be given to the evaluative judgments of separate attributes. Specifically, two connections can be discerned which involve the use of attributes. Firstly, the object needs to be associated with certain attributes, represented in the *object-attribute connection.* Secondly, the attribute itself has to be evaluated, represented by an *attribute-evaluation connection*. The attitude then is based on the sum, or combination of evaluations of attributes. Figure 2 displays the connections between these object-association evaluations. So far, at least one important remark should be made in relation to the evaluation of the attributes. The definition considers the attitude as a sum of (attribute) evaluation; however, a requirement for these attributes to be summed and weighed by an individual is that they are perceived as compensatory attributes. Compensatory strategies allow for attribute evaluations to be additive, while non-compensatory attributes are non-additive and thus inhibit all other attributes (e.g. Foerster, 1979; Sanbonmatsu & Fazio, 1990). Therefore, a summation of multiple attributes is only viable when none of the attributes are considered non-compensatory. In such cases the attitude can be constructed solely based on evaluation of one non-compensatory attribute and there is no sum of multiple evaluations as long as the non-compensatory attribute is present.

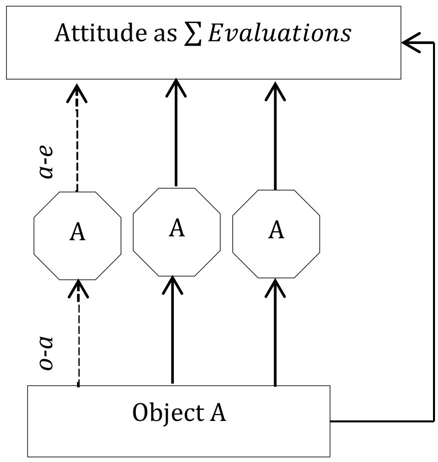

Figure 2*: A^1, A^2, A^3 represent attributes of object A. Lines represent object-attribute relations (o-a) and attribute-evaluation (a-e) relations.*

Attribute appraisal and information processing

Now that the place of attributes within the model has been described, the next step is the process through which attributes become important nodes for attitude formation. Foremost, attitudes formed through evaluating a novel object's attributes need to be constructed and require more effort than do attitudes formed through the direct route, since these latter ones are automatically and directly accessed. For the attitude to be successfully formed through the attribute route, both the object-attitude and attribute-evaluation connections need to be present.

In these cases, at least some relevant knowledge related to the attributes must be stored in memory in order to form the connections. For example, absence of the object-attribute relation could be expressed as an individual's' inability to associate nanotechnology with usefulness (wherein nanotechnology is the attitude-object and usefulness the attribute). Since usefulness in this case is not considered an attribute of nanotechnology, it cannot be evaluated in relation to nanotechnology to form an attitude. Similarly, inability to sufficiently evaluate an attribute (positive or negative) when the initial object-attribute connection is present may be exemplified as a lack of knowledge or prior experiences with the attribute itself, therefore the attribute-evaluation connection cannot be made.

Thus, it is stored knowledge that allows for evaluative judgments of the attributes themselves by means of appraisal of the attributes associated with the object; the existence of the object-attribute and attribute-evaluation connections is dependent on prior knowledge. However, the extent to which individuals are motivated to deliberately evaluate these attributes varies (Fazio, 2007). This variance in extents of information processing is commonly reflected in dual-process theories of attitude (Chaiken, 1980; S. Chen & Chaiken, 1999; Petty & Cacioppo, 1981). Amongst these dual-process theories, the elaboration likelihood model (Petty & Cacioppo, 1981, 1986; Petty & Wegener, 1999) is based on two routes of different information processing: high involvement (central route) and low involvement (peripheral route). Highly involved individuals are considered more capable and motivated and in such cases the amount of deliberation and effort to construct new attitudes increases (Fazio, 1990, 2007). Since they are based on information as a result of more elaborate appraisals, this process is more likely to form more consistent and more numerous object-association evaluations with greater resistance to change and becoming better predictors of behavior (Chaiken, Duckworth, & Darke, 1999). In other words, it has the ability to form stronger attitudes by being able to link attributes with the object more effectively and possibly also allow for more extensive attribute evaluations. Low involvement processing, on the other hand, relies on heuristics and peripheral cues (S. Chen & Chaiken, 1999; Solomon, Bamossy, Askegaard, & Hogg, 2010); information processed through this route, be it conscious or unconscious, will thus lead to weaker attitudes because they are based on less secure knowledge. As a result, the connections between the object and the attribute, as well as between the attribute and its evaluation are weaker. For example, whether nanotechnology possesses the attribute of 'safe' may be more easily swayed when it is based on unreliable information. Attitudes based on extensive processing of knowledge (i.e. cognitively formed), on the other hand, will prove much more stable.

Furthermore, the activation and accessibility of knowledge play important roles in the degree of personal involvement (Kruglanski & Higgins, 2007). Besides determining the means of information processing (i.e. through high or low involvement), the knowledge individuals choose to access and activate in order to learn also varies and is subject to contextual influences (Haddock, Rothman, & Schwarz, 1996). Consequently, the strength of an attitude that is based on knowledge can be seen as a function of attitude accessibility (Fazio, 2007; Smith, Fazio, & Cejka, 1996). *Accessibility* herein is defined as a temporary state that activates knowledge based on prior processing of stimuli (Kruglanski & Higgins, 2007) within a certain context. Likely, attitudes relating to nanotechnology are not very accessible in memory. However, they can be constructed based on attributes on which knowledge was already formed in previous occasions. A requirement for the accessibility of knowledge is its *availability*, which is defined as the extent in which the required knowledge is present in memory (Higgins, 1996). This definition of availability fits within the object-attribute and attribute-evaluation connections. Availability therein can be explained as the extent in which an individual associates an attribute with an object, and/or the attribute with an evaluation. For example, if one does not associate any kind of risk with nanotechnology, the connection between nanotechnology and risk as an attribute is unavailable. The accessibility and availability of knowledge is thus a prerequisite for the formation of the attribute-object and object-evaluation connections. Whenever information (e.g. relating to the presence of attributes) is available as well as made accessible or salient, it has the power to influence the attitudinal evaluations given by individuals, although the extent of this influence varies (Fazio, 2007). Specifically, within the context of nanotechnologies, existing associations are usually weak or non-existent. Attitudes will then have to be constructed as a contextual demand to evaluate the object, which then allows them to be affected by information that is salient at that moment more so than when automatic associations occur (Fazio, 2007). Therefore, which linkages between objects, attributes, etc. are made is to some extent dependent on the context and the salient information within it (e.g. Schwarz, 2007; Schwarz & Bohner, 2001), which in turn can be influenced e.g. through priming processes (see Dunton & Fazio, 1997; Sherman, Rose, Koch, Presson, & Chassin, 2003).

To conclude, when forming attitudes through means of attribute appraisal, both connections between the object and the attribute, as well as between the attribute and a positive of negative evaluation must be present (Figure 2). In order to form these connections, some knowledge must be present and it must become accessible, which is subject to contextual influences. How this information is processed, however, is influenced by individual involvement. This interplay of factors leads to the next important aspect related to attributes as a node in attitude formation: the processes of learning.

The role of learning processes

At least some knowledge needs to be present in order to form the relations displayed in Figure 2, which is especially important in the attitude formation of novel objects, since direct responses are unlikely to be present. Yet such knowledge is likely more available than may be apparent; people form attitudes despite not having much experience with the specific object (Scheufele & Lewenstein, 2005; Slovic, 1987) which implies they draw upon knowledge and learning in some way to form their evaluations. Especially interesting in the case of attribute-attitude connections are the notions of similarity and generalizability. Attributes even of novel and 'unknown' objects often share a degree of similarity with other objects with which individuals do have some prior experience. In this view, they are the collection of attributes of which a certain extent is shared between other objects. Objects that share more attributes between them are thereby more similar to each other (Tversky, 1977). The role of such similarities and the learning processes connected to them has been an important point of discussion within cognitive sciences.

<u>High involvement: analogical learning</u>

These aspects of learning through similarities are consistent with the learning process dubbed 'learning by analogy'. Learning by analogy uses the human mind's capability to actively seek out familiarities between objects or situations and if deemed necessary, allows for the creation of similarity (Gentner & Holyoak, 1997). It can be considered as part of a process of internal knowledge transfer; transferring knowledge from familiar to novel domains by means of analogy, focusing on the degree of association between the 'base' (familiar) and 'target' (novel) objects (Gregan-Paxton & John, 1997). One new or neutral object is paired with an existing one, thereby enabling knowledge and valence transfers of one object onto the other. The concept of valence, that is, negative and positive evaluations is important here, as the majority of what humans do or do not like seems learned rather than innate (Rozin & Millman, 1987). The process of analogous learning can provide an answer as to how humans learn to value such new situations in which knowledge of specific objects is sparse. Delving deeper into the workings of analogous learning, previous research indicates that within the analogical learning process, several phases can be distinguished (Anderson & Thompson, 1989; Gentner, 1989; Gentner & Markman, 1997; Gregan-Paxton & John, 1997; Reeves & Weisberg, 1994). This section discusses three relevant phases as laid out by Gregan-Paxton and John (1997). The phases include: (1) accessing the base domain, (2) the mapping process of the base domain to the target domain and (3) the knowledge transfer from the base to the target. These are displayed in Figure 3.

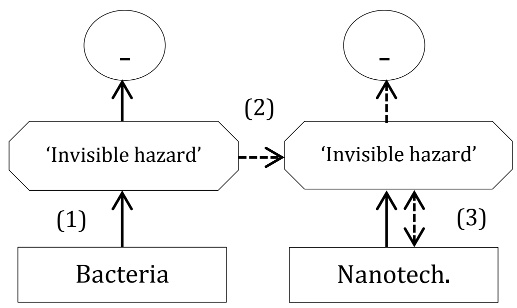

***Figure 3**: Integration of mapping and transfer systems in the model. ▭ Represent objects; ⬭ represent attributes; ◯ represent valence. - - - -> Indicate mapping connections*

Firstly, gaining access to the base domain relates to memory and the ability to access knowledge based on prior experiences. Therefore, the knowledge needs to be available in memory and accessible within the context (Kruglanski & Higgins, 2007), which also indicates that analogical learning is context sensitive to a certain extent. In the case of nanotechnology such knowledge is likely absent, limiting the 'automatic' response by which an attitude can be formed. However, the process of analogical learning instead can form analogies based on individual object *attributes*, which is much more likely to occur. Secondly, the mapping process 'fits' the base and target domains, allowing for knowledge to be transferred. This can be expressed as a measure of similarity between objects and their attributes. Thirdly, a decision has to be made to transfer the knowledge, based on the underlying degrees of similarity. Analogous learning, fits in high involvement situations, as it is an active learning process requiring the individual to actively associate the attributes or objects to be evaluated with pre-existing knowledge (Greenwald & Leavitt, 1984; Solomon et al., 2010). The processes of mapping and making knowledge accessible within analogical learning, as well as constructing a measure of similarity require rather extensive deliberation.

Using an example to visualize and integrate the process, both nanotechnology and microbial bacteria can have the attribute of being 'invisible hazards', that is, they cannot be observed through the naked eye and can prove hazardous e.g. they may cause illness. Using the bacteria as the base object, this attribute is valued negatively in the example. It also functions as a source of previous knowledge, that is, the person realizes and already knew bacteria cannot be seen normally and can be dangerous. Thus the attribute knowledge is retrieved from memory rather than constructed anew. The mapping process can allow for the attribute 'invisible hazard' of bacteria and nanotechnology to be considered similar to each other, thereby enabling a transfer of valence from the base to the target domain of nanotechnology, as shown in Figure 3.

Conclusively, analogous learning is a learning process through which the object-attribute (o-a) relation and the attribute-evaluation (a-e) relations can be created or altered (e.g. when weak linkages are present). It may create an object-attribute relation through being able to induce an attribute to an object. For example, the attribute 'invisible hazard' might be attributed to nanotechnology (i.e. made accessible) only after using the analogy with bacteria. It can also provide the valence solutions of attributes described as the attribute-evaluation relation. Since the 'invisible hazard' attribute of the example had already been valenced negatively when evaluating bacteria, the analogy can also provide the same valence for nanotechnology because it possesses the same (or a similar) attribute.

<u>Low involvement: mere exposure</u>

While analogical learning is mainly related to high involvement information processing and more active participation, low involvement information processing follows a different route. Rather, it draws upon mere exposure effects which state that the attractiveness of an object may increase and sometimes decrease as a result of repeated exposure (Zajonc, 1974). Through this process of incidental learning, individuals pick up information in a more passive manner by mere exposure to stimuli (Solomon et al., 2010). Mere exposure effects are, like the process of analogical learning, also subject to contextual influences; the settings in which exposure takes place can influence valence outcomes (Brickman, Redfield, Harrison, & Crandall, 1972; Perlman & Oskamp, 1971). When neutral novel stimuli are paired with positively or negatively laden stimuli, mere exposure can lead to the neutral stimuli to be evaluated positively or negatively according to which stimuli they are paired with (Burgess & Sales, 1971). Furthermore, exposure has the ability to create familiarity between object attributes, increasing their similarity and eventually their liking (Moreland & Zajonc, 1980; Zajonc, 1968). This is similar to associative learning processes based on (evaluative) conditioning (see e.g. De Houwer, Thomas, & Baeyens, 2001; Greenwald, 1968; Olson & Fazio, 2001, 2002). The creation of familiarity allows individuals to incidentally learn to categorize objects (Folstein, Gauthier, & Palmeri, 2010; Zajonc, 1974), which also implies that they are evaluated in some way.

The process of mere exposure can work in several ways. A more direct approach features two attitude objects or stimuli, which are then paired together consistently. Continuing with the example of analogical learning, bacteria can be paired repeatedly with nanotechnology and solely this continuous exposure should lead to a transfer of (likely negative) valence from bacteria to nanotechnology. This approach largely forgoes the objects' attributes; it is mainly the objects themselves, as a whole, that are paired. However, this does not exclude an approach based on attributes, although the difference seems mainly a matter of perception. For example, pairing riskiness with nanotechnology will create an association in which riskiness can be seen as an attribute of nanotechnology, thereby creating the object-attribute connection and transferring the existing (negative) valence of risk as the attribute-evaluation connection.

As a result, exposure effects can lead to similar outcomes as learning by analogy, even though the process is different. Repeated exposure of a novel object paired with another (negative or positive) stimulus leads to incidental associations, much like the more deliberate analogical learning. Conclusively, mere exposure learning offers a solution for low involvement processes. It fulfills a similar function as analogical learning, albeit through a different process. Analogical learning uses a process of knowledge activation, mapping and transferring knowledge to facilitate relations between the attitude object, its attributes and their evaluations. Mere exposure, on the other hand, creates and strengthens associations by repeated exposure of novel stimuli paired with known stimuli, but may also weaken by repeated nonuse (e.g. Sanbonmatsu, Posavac, Vanous, Ho, & Fazio, 2007). Both of these processes are able to form attitudes by means of learning.

3. Integrating the model

This chapter integrates the analysis in the previous chapter and presents a model of attitude formation through evaluation of object attributes, as displayed in Figure 4. A direct route towards attitudes is represented as an automatic response for stronger attitudes, stored in memory and readily accessible. However, when attitudes towards unfamiliar, novel objects are concerned, attitude formation through evaluation of the attitude-objects' attributes becomes a viable route to construct an attitude. This attribute-based perspective views the object as a collection of attributes; by evaluating the individual attributes one may form an evaluative judgment of the object as a whole. While the object itself may be considered novel, individual attributes will most likely share similarities with other objects. In addition, the attributes themselves may be evaluated positively or negatively. The model draws upon two learning processes that utilize comparisons or associations between two objects. These processes are learning by analogy and mere exposure effects, which are used to explain how individuals can associate a novel object with attributes and how those attributes are connected to their respective valence evaluations. The extent to which these relations can be evaluated as a result of deliberation, accessibility of the information, involvement of the individual and so forth, affects how secure and strong the attitude will become. Importantly, which attributes are inferred from one object to the other (e.g. the familiar object and the novel object) depends on which objects are associated. Association, either through exposure or by analogy, of a highly positively evaluated object and its attributes is likely to transfer more positive valence from one object to the other. It thereby influences the final attitude through the attribute-evaluation linkage. Lastly, the summation of both positively and negatively evaluated attributes forms the attitude towards the object, although the possible presence of non-compensatory attributes inhibits other (compensatory) attributes and can prevent summation of multiple attributes.

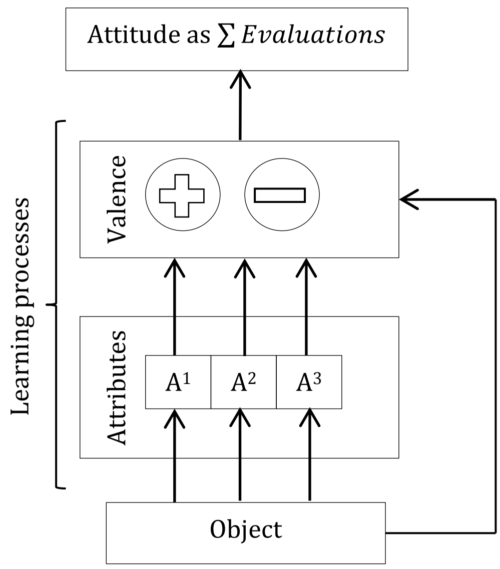

***Figure 4**: Representation of the model.*

Furthermore, once an attitude is constructed (e.g. through the evaluations of the attributes), future confrontations with the attitude object can evoke the existing evaluation that was made previously, rather than continuously and repeatedly deliberating knowledge of the attributes (Fazio, 2007). After having formed a more rigid attitude through evaluation of attributes, the attitude becomes more readily accessible and may eventually become an automatically cued response when an individual is confronted with the object. Thus, as a result of repeated confrontation with the object, the direct route eventually becomes the go-to response when confronted with the object, since it provides a quicker and less cognitively taxing solution (Pieters & van Raaij, 1988). It is similar to an affective reaction which uses the previous analysis as a heuristic to justify the evaluation/attitude. However, individuals can also re-visit the object attributes when they have the capability and motivation to do so (Fabrigar, Petty, Smith, & Crites, 2006; Sanbonmatsu & Fazio, 1990) and when there is a valid reason for doing so. New information that has become salient might lead to a need for re-evaluation of the attributes and could change or add existing connections.

In cases where novel objects are involved, this transition from a more extensively formed attitude based on object attributes to an automatic response, means that attitudes can change as (public) awareness and knowledge about these technologies grows over time. However, this also means that when these attribute-based attitudes become more solidified and ingrained in our lives through repeated adjustment and improvement, they can become automated responses, increasingly resistant to change.

4. Discussion and conclusions

This literature review presents a model of attitude formation through evaluation of the attitude objects' attributes, focusing on explaining means of attitude formation towards novel objects and specifically, relating to the case of nanotechnology. By integrating existing views on attitude literature (e.g. Azjen, 1991; Fazio, 2007; Fishbein & Azjen, 1975; Schwarz, 2007; van Overwalle & Siebler, 2005), the model posits two routes to attitudes. Firstly, a direct route can be established which is cued automatically and rapidly, and is generally used for strong connections and familiar objects. This route requires accessible and available knowledge stored in memory, which is usually non-existent or weakly present when considering novel objects. Attitudes considering new objects (e.g. nanotechnologies) may instead be constructed on the bases of their attributes. The attitude object therein is a collection of attributes that it is perceived to possess. These attributes, in turn, are individually valued positively or negatively in relation to the object. This attribute-oriented approach implies that, although an object as a whole may be novel, it most likely shares similarities with other, previously encountered objects. Such similarities may present themselves in the attributes of objects; the object is unfamiliar but (some) attributes are not.

The model adds to current understanding of attitude formation towards novel objects by assimilating learning processes into the routes attitude formation, not only explaining which linkages are made, but also showing how these can come to exist. These learning processes allow for individuals to create associations between familiar and novel objects; the object-attribute relations and attribute-evaluation relations can be constructed by using existing knowledge. Highly involved individuals can use analogies, which may be cued in context (e.g. through media or advertisement) to compare attributes in a more extensive manner. Low involvement situations can create associations by means of mere exposure. The extent to which these learning processes are successfully executed determines the strength and presence of the relations between the object and the attribute, as well as the attribute and its evaluation. How people learn is thus connected to how and which attitudes they form.

Relating to the case of nanotechnologies, attribute-based means of forming attitudes can be relevant in determining the public acceptance (or rejection) of nanotechnology. How the public will react to nanotechnology remains largely unclear (Siegrist, 2007), which may well be affected by a general lack of knowledge and awareness regarding these technologies. Information about innovations aimed at the public generally focuses on more cognitive aspects (Dudo, 2013), which may activate more deliberate processing particularly relevant to the attribute-based attitudes as discussed in this study (see also S. Lee, Ha, & Widdows, 2011). Furthermore, previous studies have shown e.g. that people use available information about risks and hazards to evaluate new technologies (Visschers, Meertens, Passchier, & De Vries, 2007); the evaluation of nanotechnology is thus related to the extent in which it can be compared to other technologies. When considering that people may relate nanotechnology to the generally rejected genetic modification technologies, it could prove detrimental indeed. On a larger scope, and relating back to the model, this shows that which attributes are associated with the object is malleable to some extent, especially for abstract attributes. It depends on available knowledge and which associations can be made with similar objects. Comparing nanotechnology with gene technologies may transfer negative attributes, such as hazardous and unnatural, onto nanotechnology. On the other hand, evaluating nanotechnology in relation to e.g. computers may result in more positive transfers of attributes such as usefulness and progression. Associations like these could snowball into self-fulfilling prophecies and confirmation bias; when an object is associated with certain positive or negative outcomes, people will assimilate their attitudes to fit with these 'truths'. Depending on the associations, nanotechnology may become positive or negative, even though the object remains the exact same. This highlights the role of information sources e.g. media such as the news, advertisements, magazines etcetera, for they can (explicitly or implicitly) condition the public to make associations and make salient analogies individuals can then process to form their evaluations.

Relating to other research, at least some important notions should be made in relation to the findings of this paper. Firstly, while the definition of attitudes in this research does not exclude affective attitudes, the nature of the literature reviewed tended to the cognitive side of attitude formation. It is possible that highly affective responses could be processed differently in the model than cognitive responses. Recent studies show that such affective response can be important when considering novel technologies (van Giesen et al., 2014). Secondly, the ambivalence of nanotechnology remains relevant. The model effectively solves matters of ambivalence through displaying individual attributes; each positive or negative. The sum of attitudes then should become either negative or positive. In practice, however, such a process could prove more complex. People may decide e.g. to confirm to one side (somewhat akin to inhibiting effects of non-compensatory attributes) or postpone their judgment (Fischer et al., 2013). Lastly, the more general relations between attitudes and behavior remain contested. Whether negative or positive attitudes will lead to certain behaviors remains disputable. As a result, this paper focused on attitude formation in itself rather than behavioral implications.

In conclusion, the attribute-oriented approach of attitudes could prove valuable for understanding the public attitudes towards nanotechnology. It is important to note that in the current situation the links between nanotechnology and the attributes it is perceived to possess, as well as whether these attributes should be positive or negative, are weak amongst the public. Yet, as time progresses and people gain more experience with nanotechnology, they are more often prompted to evaluate and thereby form attitudes. Increasing knowledge through learning and repeated confrontations will strengthen the associations between the technology and how it is evaluated. Ultimately, the term nanotechnology will transform from a novel, unknown object to something familiar. As a consequence, those attitudes will become increasingly solidified in our thoughts and much harder to adjust. Whether nanotechnology is to be seen as a positive or negative development will thus be shaped sooner rather than later and will become less malleable over time.

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