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Addressing Chemophobia: Informational versus affect-based approaches

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ABSTRACT

This study investigated the effect of two communication strategies (informational and affect-based) in reducing chemophobia, the irrational fear of chemicals. In an online experiment, participants (N = 448) were randomly assigned to one of three groups ("control", "knowledge", or "affect" group). The following dependent variables were assessed: chemophobia, knowledge of basic toxicological principles, affect towards chemicals, benefit perception of the use of chemicals, and preference for natural substitutes in consumer products. The results showed that only the informational approach, which conveys knowledge of basic toxicological principles, significantly decreased chemophobia and the preference for natural substitutes in consumer products. The affect-based approach significantly increased positive affect towards chemicals and the benefit perception of their use, but did not decrease chemophobia. This suggested that the provision of relevant information about basic toxicological principles is a more effective strategy than merely addressing laypeople's affect towards chemicals to reduce chemophobia. Relevant knowledge could be taught in schools or disseminated by toxicologists and scientists who are trusted by the public.

1. Introduction

Chemophobia is the irrational fear of chemicals (Entine, 2011; Gribble, 2013; Michaelis, 1996). People exhibiting chemophobia tend to be overly concerned with the risks of chemicals and believe that chemicals are harmful at any concentration and exposure level (Kraus et al., 1992; Mertz et al., 1998; Saleh et al., 2019; Slovic et al., 1995). In fact, for lay-people, the term "chemicals" likely refers to synthetic chemicals, since chemophobia is more strongly associated with the fear of exposure to synthetic chemicals than natural ones (Entine, 2011; Gribble, 2013; Rozin, 2005; Rozin et al., 2004; Saleh et al., 2019; Siegrist and Bearth, 2019). People expressing chemophobia tend to prefer chemicals of natural origin over synthetic chemicals in products. This is because the former is perceived as safe and healthy while the latter is perceived as inherently dangerous (Entine, 2011; Rozin et al., 2012; Rozin et al., 2004). Thus, the risk of a chemical is judged based on its origin (man-made or found in nature), despite the fact that this is not an indicator of its toxicity (Bearth et al., 2019; Saleh et al., 2019).

People's risk perceptions can influence their decision-making and their behaviors (Slovic, 1987; Slovic et al., 2005; Williams and Noyes, 2007). Hence, chemophobia may prevent people from making informed decisions regarding chemicals and consumer products. For instance, people with high levels of chemophobia may reject certain chemicals and products (e.g., pharmaceutical drugs, vaccines) that are beneficial, simply for being man-made and thus, perceived as unsafe (Entine, 2011; Lynch and Berry, 2007).

Previous research suggests that a better understanding of basic toxicological principles is associated with lower levels of chemophobia (Bearth et al., 2019; Saleh et al., 2019). However, this association does not infer a causal relationship between knowledge and chemophobia. An experimental examination of this relationship can help determine how to address chemophobia. Moreover, risk literature stresses the role of affect for consumers' risk perceptions and decision-making since people may lack the knowledge to make an informed decision (Alhakami and Slovic, 1994; Finucane et al., 2000; Slovic et al., 1997).

Therefore, the present study examines the effect of two different communication strategies, informational and affect-based (i.e., based on emotions), on people with chemophobia and their perceptions of synthetic and natural chemicals. Overall, the findings of this study could provide potentially effective risk communication strategies that could address laypeople's misconceptions of toxicological principles and, consequently, chemophobia.

1.1. Theoretical background

1.1.1. Chemophobia: origin and consequences

Laypeople tend to possess a distorted image of the risks of (synthetic) chemicals while being unaware of their benefits. The term

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"chemical" itself is stigmatized and often associated with cancer, toxicity, and death (Ropeik, 2015; Rozin et al., 2004; Saleh et al., 2019). Consumer goods companies avoid this stigma by replacing E numbers or synthetic-sounding ingredients with more appealing names such as "aroma" for foods or "fragrances" for perfumes (Asioli et al., 2017; Gribble, 2013). "Chemical-free" or "green" labels are also used on different consumer goods (e.g., food, cleaning products), which may contribute to peoples' fears of chemicals and the erroneous belief that a chemical-free life is possible (Entine, 2011; Francl, 2013).

Furthermore, people tend to believe that anything produced by human intervention cannot be equal to what originates in nature (Principe, 2013; Rozin, 2005). What is perceived as natural holds positive connotations in many contexts (e.g., health, medicine, food production (Meier et al., 2019; Rozin, 2005; Rozin et al., 2012; Rozin et al., 2004). Rozin and colleagues have argued that ideational and instrumental beliefs drive preferences for natural chemicals (Rozin, 2005; Rozin et al., 2004, 2012). Ideational beliefs account for the perception of chemicals of natural origin as morally superior to synthetic chemicals. Instrumental beliefs, however, focus on specific attributes of chemicals, such as chemicals of natural origin being safer and healthier than synthetic chemicals (Rozin, 2005; Rozin et al., 2004). Anecdotal evidence suggests that people who are afraid of chemicals prefer natural ingredients over synthetic ones in consumer products (Entine, 2011). In fact, the preference for chemicals of natural origin in different consumer products (e.g., food, medicine, household cleaning products, personal care products) is well-documented in research but has never explicitly been linked to chemophobia (Apaolaza et al., 2014; Bearth et al., 2014; Chermahini et al., 2011; Dickson-Spillmann et al., 2011; Lynch and Berry, 2007; Meier et al., 2019; Rozin et al., 2004). However, chemicals of natural origin in consumer products do not necessarily make these products less risky or healthier. The assumption that any product labelled "natural" is safer and better for health than regular products is inaccurate and may have consequences. For example, people exhibiting chemophobia are more likely to take herbal medicine than over-the-counter and prescription drugs because herbal medicine is perceived to be natural and safer than synthetic medicine (Lynch and Berry, 2007). Moreover, they may view a hazardous consumer product, such as essential oils or eco-labelled drain cleaner, as natural and safe and unknowingly endanger their own health, as well as the health of others (Bearth et al., 2017; Gribble, 2013). In addition, people may support bans on certain chemicals (e.g., synthetic agriculture chemicals, vaccines, food additives) that may be irreplaceable or even replaced with natural alternatives that are not necessarily safer, more effective or efficient (Gribble, 2013; Winter and Katz, 2011; Entine, 2011; McKee and Bohannon, 2016). Lastly, risk management authorities might waste national funds responding to such unwarranted scares (Monro, 2001; Ropeik, 2012). Therefore, reducing chemophobia is important to prevent unnecessary overreactions to synthetic chemicals and ensure informed decision-making.

1.1.2. Chemophobia: the role of knowledge vs. affect heuristic

Several misconceptions regarding chemicals and basic toxicological principles have been identified in the literature (Bearth et al., 2019; Chalupa and Nesmerak, 2014; Entine, 2011; Francl, 2013; Kauffman, 1989; Kraus et al., 1992; Saleh et al., 2019). People who are afraid of chemicals might infer definite adverse health effects from minor doses and exposure to them (Bearth et al., 2019; Dickson-Spillmann et al., 2011; Kraus et al., 1992; Saleh et al., 2019; Slovic et al., 1997). In addition, higher levels of chemophobia are associated with the misconception that synthetic and natural entities are chemically different (Bearth et al., 2019; Saleh et al., 2019). Lastly, natural chemicals are not necessarily recognized as "chemicals" since people associate the word with synthetic ingredients.

Previous research showed that chemophobia is related to low levels of knowledge about toxicological principles. A basic understanding of chemicals and basic toxicological principles may reduce chemophobia and support informed decision-making (Bearth et al., 2016; Bearth et al., 2019; Dickson-Spillmann et al., 2011; Kraus et al., 1992; Saleh et al., 2019; Shim et al., 2011; Siegrist and Bearth, 2019). However, due to the lack of knowledge and resource restraints (e.g., lack of time, motivation or attention), laypeople do not always rely on the analytical evaluations of risks (Slovic et al., 2002, 2004). In fact, in the absence of knowledge, people may rely on heuristics, which are mental shortcuts to make quick decisions. The "affect heuristic" might be one heuristic people employ when judging chemicals. According to the affect heuristic, chemicals may evoke images and associations tagged with negative or positive feelings. People rely on these feelings (i.e., their affect) to judge their acceptance, risk and benefit perception of a particular issue (Alhakami and Slovic, 1994; Finucane et al., 2000; Slovic et al., 2005). A negative affect towards an issue could lead to a higher risk perception and a lower benefit perception of that issue and vice versa (Finucane et al., 2000; King and Slovic, 2014; Slovic et al., 2004). The use of affect is faster and can be more efficient than undergoing analytical evaluations (Finucane et al., 2000; Gigerenzer and Gaissmaier, 2011). Nonetheless, decisions made by relying on affect might be biased and not in the person's best interest (Ropeik, 2011; Siegrist and Sutterlin, 2014; Slovic et al., 2002, 2004). For instance, previous research suggests that a significant proportion of people have neutral or even negative associations with chemicals and thus, negative affect (Saleh et al., 2019). This negative affect might drive people's negative perceptions of chemicals and chemophobia (Entine, 2011; Saleh et al., 2019). Therefore, de-stigmatizing chemicals might be necessary to reduce negative affect and unwarranted risk perceptions of chemicals.

1.2. Study aims and design

Thus far, risk communication efforts to de-stigmatize synthetic chemicals, clarify misconceptions, and reduce concerns related to chemicals have rarely been evaluated systematically (Bearth et al., 2016; Chalupa and Nesmerak, 2018; Royal Society of Chemistry, 2015). Therefore, the goal of the present research was to investigate strategies that successfully reduce chemophobia and increase knowledge of toxicological principles. More specifically, the primary objective was to test the effect of two communication strategies on chemophobia. The first strategy was based on the information provision of basic toxicological principles, such as the dose-response relationship. The second strategy was an affect-based approach focusing on de-stigmatizing chemicals and conveying their benefits to individuals and society. Based on previous literature (Bearth et al., 2016, 2019; Dickson-Spillmann et al., 2011; Saleh et al., 2019; Shim et al., 2011), it was hypothesized that information provision would reduce chemophobia. However, the affect heuristic also states that, in the absence of knowledge, people might rely more heavily on their affect when judging a risk. Thus, it was hypothesized that the affect-based approach would also reduce chemophobia. Therefore, the main focus of this study was to investigate which strategy would be more effective for reducing chemophobia. The secondary objective was to investigate the impact of the two communication strategies on people's preferences for natural substitutes in consumer products.

2. Methods

2.1. Experimental design

The study has a between-subjects design with two experimental groups and a control group. Prior to being randomly assigned to one of the three groups, participants gave their informed consent and answered basic socio-demographic questions. Then, each group of participants was presented with a different video. The first experimental group ("affect" group) was shown a video about the widespread uses of chemicals in different consumer products and services (e.g., in food, water, clothes, electronics, cars, medicine) to portray the beneficial

Table 1
Socio-demographics total and by groups.

		Groups			
		Total (N = 448)	Control (n = 151)	Knowledge (n = 155)	Affect (n = 142)
Age	M^a $(SD)^b$	61.76 (13.44)	60.16 (14.14)	62.28 (12.92)	62.87 (13.16)
Gender	Female	180 (40.2%)	60 (39.7%)	61 (39.4%)	59 (41.5%)
	Male	268 (59.8%)	91 (60.3%)	94 (60.6%)	83 (58.5%)
Education	Low	132 (29.5%)	50 (33.1%)	40 (25.8%)	42 (29.6%)
	Middle	140 (31.3%)	42 (27.8%)	52 (33.5%)	46 (32.4%)
	High	176 (39.3%)	59 (39.1%)	63 (40.6%)	54 (38.0%)

[a] Mean[b] Standard deviation.

aspect of chemicals and its role in everyday life. For example, the video shows the presence of synthetic fibers in medical wear for protection, safety and hygiene. This video was developed and published in 2011 by the United Nations Educational Scientific Cultural Organization (UNESCO, 2011). The second experimental group ("knowledge" group) watched a video explaining basic toxicological principles (e.g., dose-response relationship, natural and synthetic chemicals toxicity, etc.) to provide basic information on chemicals and toxicological principles. The video's content was based on the findings of two previous studies on people's misconceptions and knowledge gaps about toxicological principles (Bearth et al., 2019; Saleh et al., 2019). In order to ensure comparable conditions in the control group, another video was developed on a topic unrelated to the study: black holes. The "control" group video was timely due to the recent release of the first picture of a black hole. The "knowledge" group's experimental video and the "control" group's video were made by the authors for the purpose of this study. The contents of the two videos were discussed with experts to ensure correctness and accuracy. All three videos were of the same length (2 min 40 s) (cf. all three videos in Appendix A). The sources of the videos were revealed at the end of the experiment.

After presenting the videos, participants were asked whether they had any technical difficulties when playing the videos (visual or auditory). Specific questions regarding the visual content of the videos were asked to ensure that people paid attention and did not fast-forward or skip sections. Participants were then asked to evaluate the quality of the videos, whether they had ever seen the videos or similar videos before, and whether they learned new information. Subsequently, several dependent variables (chemophobia, knowledge of basic toxicological principles, affect towards chemicals, benefit perception of the use of chemicals, and preference for natural substitutes in consumer products) were assessed. At the end of the survey, participants answered additional socio-demographic and control questions (e.g., level of education, profession). Lastly, all participants were provided with an optional written text that cleared up any uncertainties raised by the questionnaire.

2.2. Participants

A sample of Swiss German-speaking participants from the online panel of the Consumer Behavior Group at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) was recruited. The registered panel members had previously agreed to participate in the groups' studies on a regular basis. Participants were invited to take part in this online study via e-mail in July 2019. A reminder e-mail was sent one week after the initial invitation. To avoid selection bias, the study aim and topic were not revealed in the invitation.

Based on a prior power analysis, a sample of at least $N = 432$ participants is needed to detect a small effect size of $d = 0.15$ with a power of 0.80 (Cohen, 1988). The effect size was based on the findings of a similar prior study with videos informing consumers about the risk assessment of food additives (Bearth et al., 2016). More participants were sampled, as it was expected that some participants would have to be excluded due to technical difficulties while watching the videos or for not passing the manipulation check. A total of $N = 470$ of the $N = 973$ invited participants fully completed the online experiment without experiencing technical difficulties playing the videos, which corresponds to a response rate of 48.3%. From this sample, 22 participants were dropped from the analysis, of which 8 did not pass the manipulation check, and 14 had a profession in a chemical-related field. The final sample was composed of 448 participants (59.8% males, $M_{\text{age}} = 61.76$ years, $SD_{\text{age}} = 13.44$, range: 19–89 years). The respondents' self-reported education levels ranged from mandatory school, basic apprenticeship, prevocational school, or apprenticeship ($n = 132$, 29.5%), to high school or technical and vocational training ($n = 140$, 31.3%), and university ($n = 186$, 39.3%). There were no significant differences between the three groups in terms of education levels (χ^2 (4, N = 448) = 2.41, $p = .66$), and gender distribution (χ^2 (2, $N = 448$) = 0.17, $p = .92$). Age distribution was also not significantly different between the three groups F (2, 445) = 1.67, $p = .19$. Table 1 presents the socio-demographics of the three groups.

2.3. Materials

2.3.1. Evaluations for the overall quality of the videos

Participants evaluated the quality of the videos regarding five aspects (if the video was understandable, convincing, believable, useful, and interesting) on a Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). For each video, a scale for overall quality was calculated by taking the mean of the five quality aspects for each participant. Based on a reliability analysis (i.e., measures how strongly the items included in the scale are correlated), this overall quality scale had an excellent internal consistency with Cronbach's alpha $\alpha = 0.92$. Values of Cronbach's alpha between 0.6 - 0.7 indicate acceptable levels of reliability. Values of 0.8 and 0.9 indicate good and excellent levels of reliability respectively (Streiner, 2003).

2.3.2. Dependent variables

Chemophobia was assessed with an adapted version of a previously used measure, on a Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree) (Bearth et al., 2019; Saleh et al., 2019). The items are shown in Table 2. The scale for chemophobia was built by taking the mean of all items after conducting principal component analysis and reliability analysis. According to Kaisers' criterion and the scree plot, one-factor solutions were uncovered for the multi-item scale (cf. item-total correlations in Table 2)(Cattell, 1966). The item-total correlations show the association between each item of the scale with the total scale scores without that particular item (i.e., how well the item fits into the scale) (Streiner, 2003). These correlations revealed that one item (*it is possible to purify the body with detox treatment*) has a low correlation with the total scale ($r < 0.3$). This low correlation suggests that this item is not measuring the same construct as the other items, and should be excluded from the scale. Hence, the chemophobia scale consisted of seven items with a good Cronbach's alpha $\alpha = 0.83$ indicating that this scale is reliable.

Table 2
Chemophobia and preference for natural substitutes in consumer products: Item-total correlations (Item-total r) and scales' Cronbach's alpha (α).

Items	Item-total r
Chemophobia scale[a] (α = .83)	
I do everything I can to avoid in my daily life contact with chemical substances	.65
I would like to live in a world where chemical substances don't exist	.65
Chemical substances scare me	.64
I am scared of chemical substances I cannot pronounce	.57
In a world without chemical substances, there would be no environmental disasters	.52
The chemical industry is responsible for more people suffering from cancer	.51
I would like all chemical substances to be risk-free	.41
Preference for natural substitutes in consumer products scale[b] (α = .90)	
Everyday care products (e.g., deodorant, shampoo)	.80
Regular cleaning products (e.g., window cleaner, dish washer)	.79
"Specialized" cleaning products (e.g., descalers)	.74
Convenience food (e.g., frozen Lasagne)	.71
Beverages (e.g., flavors in soft drinks)	.69
Medicine (e.g., nasal spray, painkiller)	.66

N = 448.

The knowledge scale comprised seven items based on the validated knowledge of basic toxicological principles scale (Bearth et al., 2019; Saleh et al., 2019). The scale comprises two correct statements (items 6 and 7) and five incorrect statements (items 1–5) about toxicological principles (cf. Fig. 1). Participants could respond to each item with "right," "wrong" or "do not know." All correct responses were recoded as 1 and all incorrect and "do not know" responses as 0. Correct responses were summed for each participant to produce a knowledge score. Thus, a high score indicates high knowledge, while a low score indicates little knowledge.

Affect towards chemicals was measured by asking participants the following question: "What type of feelings are evoked in you when you think of the term 'chemical substances'?" Participants could indicate their evoked affect towards chemicals on a slider ranging from 0 (extremely negative) to 100 (extremely positive).

Benefit perception was measured with the following question: "How beneficial do you think the use of chemical substances is in consumer products?" Participants' responses were recorded on a slider ranging from 0 (not beneficial at all) to 100 (extremely beneficial).

To assess the preference for natural substitutes in consumer products, participants were asked the following question: "How important is it for you that there are natural alternatives for the chemical substances used in the following products?" Five consumer products from different products domains (food, beverages, medicine, household cleaning products, and personal care products) were listed. Participants indicated the importance of having natural chemicals in each of the five products on a Likert scale ranging from 1 (not important at all) to 6 (extremely important). Similar to the chemophobia scale, the scale for the preference for natural substitutes in consumer products was built by taking the mean of the items for the construct. For this scale, a one factor solution was found (cf. item-total correlations in Table 2). The scale also exhibited an excellent Cronbach's alpha of $\alpha = 0.90$ based on reliability analysis.

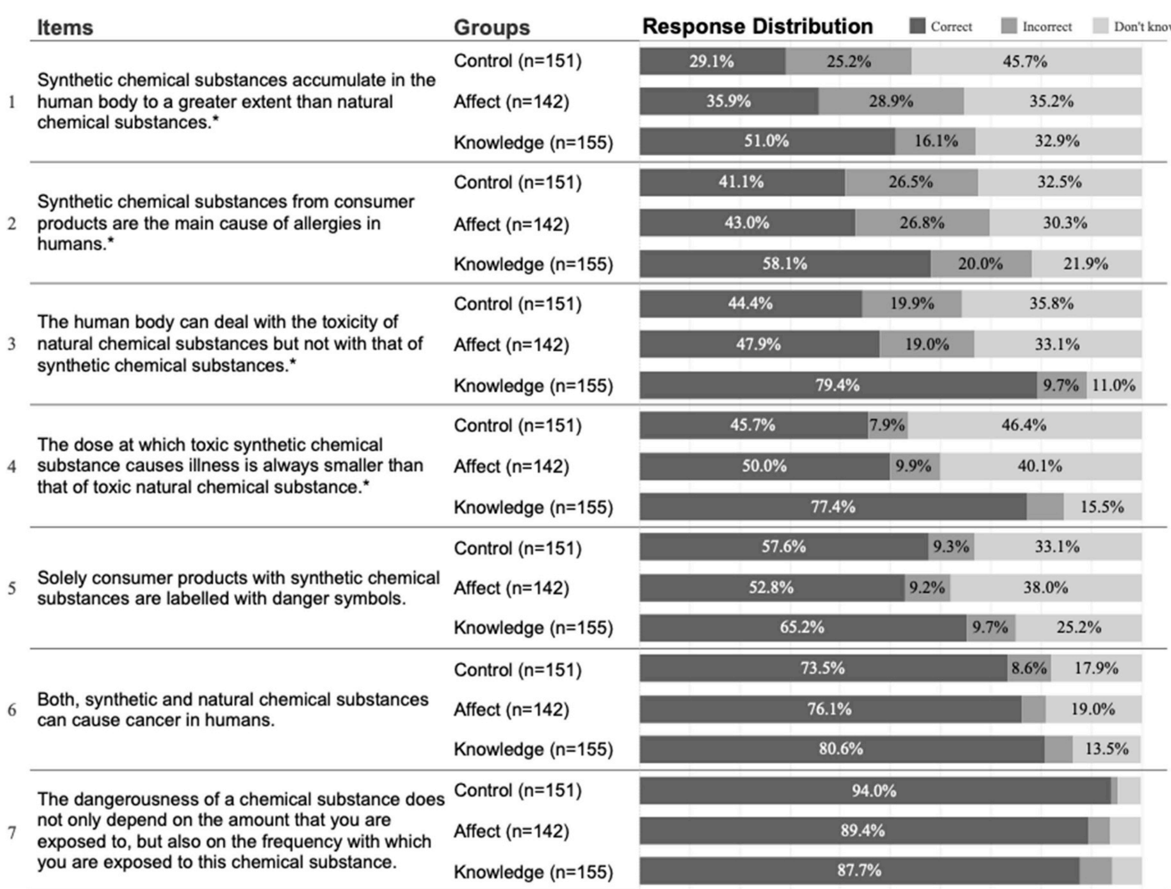

Fig. 1. Response distribution of the items regarding the knowledge of basic toxicological principles scale for the three groups.
(*) denotes items with response distributions significantly different between the three groups.

2.4. Data analysis

Data was analyzed using SPSS version 25.0 (IBM Corp, 2017). One-way analyses of variances (ANOVA) with Tukey's post-hoc tests that allows to evaluate whether and which groups differ on the variables of interest (Iversen and Norpoth, 1987), were conducted to compare the differences between the three groups on the following dependent variables: chemophobia, knowledge of basic toxicological principles, affect towards chemicals, benefit perception of the use of chemicals, and preference for natural substitutes in consumer products. Effect sizes n_p^2 were reported for results of one-way ANOVAs to assess the strength of the differences in the dependent variables due to the videos (Cortina and Nouri, 2000). Additional analyses to evaluate the relationship between knowledge provision and the communication strategies (informational and affect-based) were conducted using Chi-square tests (Ugoni and Walker, 1995). Figures featured in this study were prepared using Tableau Desktop (Tableau Software Inc, 2003) and SPSS (IBM Corp, 2017).

3. Results

3.1. Evaluations for the overall quality of the videos

The overall quality of the videos (i.e., if the video was understandable, convincing, believable, useful, and interesting) was significantly different between the groups, $F(2,445) = 31.48, p < .001$. The post-hoc tests indicated that the mean overall quality of the videos were significantly higher for the "knowledge" group ($M = 4.92$, $SD = 1.08$) than the "control" group ($M = 4.36$, $SD = 1.09$). The video quality for the "affect" group was lower than the others ($M = 3.85$, $SD = 1.30$). In addition, 45.1% of the "control" group and 36.2% of the "knowledge" group reported having learned new information from the videos, compared to 18.7% from the "affect" group, χ^2 (2, $N = 448$) = 62.19, $p < .001$.

3.2. Effect of different videos on the dependent variables

3.2.1. Chemophobia

Participants' self-reported chemophobia differed significantly between the groups, $F(2,445) = 13.32, p < .001$ (cf. Table 3). The post-hoc tests indicated that the "knowledge" group had significantly lower chemophobia levels ($M = 2.57$, $SD = 0.97$) than both the "affect" ($M = 3.06$, $SD = 0.98$) and the "control" ($M = 3.07$, $SD = 0.94$) groups (cf. Fig. 2). There was no significant difference between the "affect" and "control" groups.

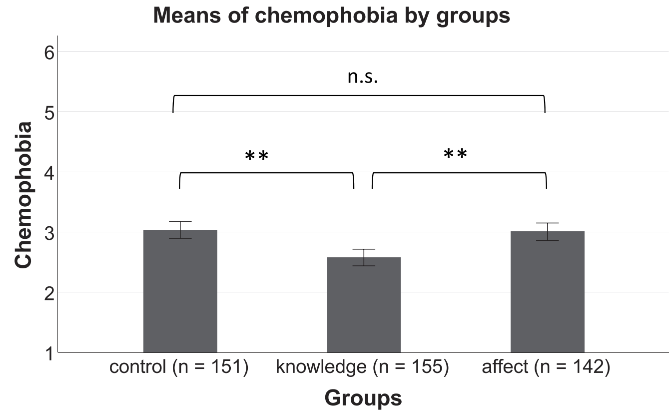

Fig. 2. Chemophobia with 95% confidence intervals by groups.
** indicates significance at p < .001
n.s. indicates significance at p > .05 (not significant).

3.2.2. Knowledge of basic toxicological principles

Overall, participants' understanding of basic toxicological principles differed significantly between the groups, $F(2,445) = 19.61, p < .001$ (cf. Table 3). The post-hoc tests indicated that the understanding of basic toxicological principles of the "knowledge" group ($M = 4.99$, $SD = 1.62$) was significantly higher than the "control" ($M = 3.85$, $SD = 1.91$) and "affect" ($M = 3.88$, $SD = 1.90$) groups (cf. Fig. 3). There was no significant difference between the "control" and "affect" groups.

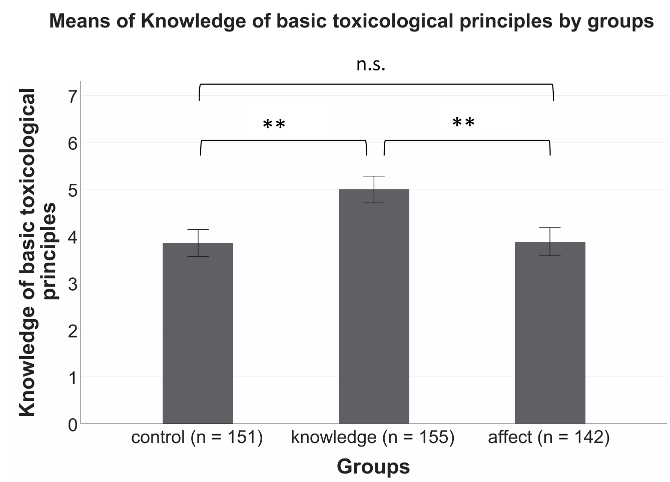

Fig. 3. Knowledge of basic toxicological principles with 95% confidence intervals by groups.
** indicates significance at $p < .001$
n.s. indicates significance at p > .05 (not significant).

Additionally, Fig. 1 shows the response distribution of the seven knowledge items, separated by groups. The response distributions

Table 3
Means (M), standard deviations (SD), and one-way analyses of variances for the effect of the three groups on five dependent variables.

Dependent Variables	Groups				
	Control ($n = 151$) M (SD)	Knowledge ($n = 155$) M (SD)	Affect ($n = 142$) M (SD)	F (2, 445)	η_p^2
Chemophobia	3.07 (0.94) $_a$	2.57 (0.97) $_b$	3.06 (0.98) $_a$	13.32**	0.06
Knowledge of basic toxicological principles	3.85 (1.91) $_a$	4.99 (1.62) $_b$	3.88 (1.90) $_a$	19.61**	0.08
Affect towards chemicals (0 = negative, 100 = positive)	48.56 (13.08) $_a$	44.03 (13.26) $_a$	54.34 (20.37) $_b$	15.86**	0.07
Benefit perception of the use of chemicals	40.67 (23.47) $_a$	51.45 (22.72) $_b$	49.31 (26.88) $_b$	8.32**	0.04
Preference for natural substitutes	4.62 (1.05) $_a$	3.97 (1.34) $_b$	4.49 (1.26) $_a$	12.04**	0.05

Means in a row that have the same subscript letter (i.e., a or b) are not significantly different from each other (reading example: The means of the "control" and "affect" groups have the subscript a, while the mean of the "knowledge" group has the subscript b. This suggests that the mean of the "knowledge" group differed significantly from the means of the "control" and "affect" groups).
**$p < .001$, F value (degrees of freedom), η_p^2: partial eta square.

related to the accumulation of chemicals in the human body (χ^2 (4, N = 448) = 28.47, p < .001), allergic reactions (χ^2 (4, N = 448) = 10.75, p < .05), toxicity (χ^2 (4, N = 448) = 47.17, p < .001), and doses (χ^2 (4, N = 448) = 40.47, p < .001) were dependent on which video the participants watched. For these items, participants responded less frequently with "do not know" responses in the "knowledge" group (10–30%) than the "affect" (30–46%) and "control" (30–45%) groups. Overall, the "knowledge" group had more correct responses (50–80%) than the "affect" (35–50%) and "control" (29–45%) groups. However, there was no association between which video the participants watched and the responses related to the regulation of chemicals (χ^2 (4, N = 448) = 5.94, p = .20), carcinogenic effects (χ^2 (4, N = 448) = 3.71, p = .45), and exposure assessments (χ^2 (4, N = 448) = 5.79, p = .22).

3.2.3. Affect towards chemicals

Participants' affect towards chemicals differed significantly between the groups, F (2,445) = 15.86, p < .001 (cf. Table 3). The post-hoc tests indicated that the reported affect towards chemicals of the "affect" group (M = 54.34, SD = 20.37) was significantly higher than the "control" (M = 48.56, SD = 13.08) and "knowledge" (M = 44.03, SD = 13.26) groups (cf. Fig. 4). There was no significant difference between the "control" and "knowledge" groups.

3.2.4. Benefit perception of the use of chemicals in consumer products

Both experimental videos had significant effects on participants' perceptions of the benefits of chemicals in consumer products, F (2,445) = 8.32, p < .001 (cf. Table 3). The post-hoc tests indicated that the "affect" (M = 49.31, SD = 26.88) and "knowledge" (M = 51.45, SD = 22.72) groups perceived higher benefits of the use of chemicals than the "control" group (M = 40.67, SD = 23.47) (cf. Fig. 5). There was no significant difference between the "affect" and "knowledge" groups.

3.2.5. Preference for natural substitutes in consumer products

There were significant group differences in the preference for natural substitutes in consumer products, F (2,445) = 12.04, p < .001 (cf. Table 3). The post-hoc tests indicated that the mean preference was lower for the "knowledge" group (M = 3.97, SD = 1.34) than the "control" (M = 4.62, SD = 1.05) and "affect" (M = 4.49, SD = 1.26) groups (cf. Fig. 6). There was no significant difference between the "control" and "affect" groups.

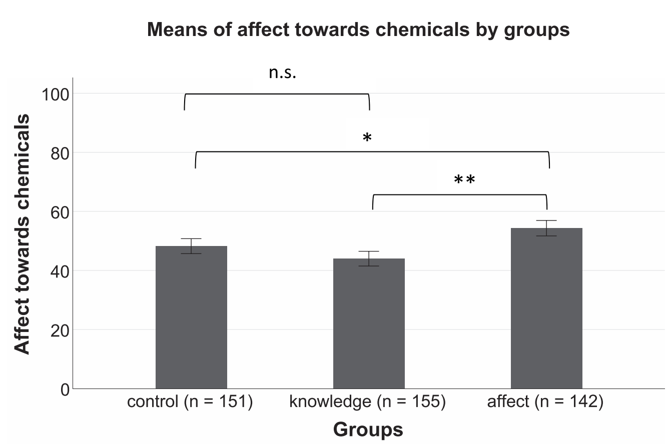

Fig. 4. Affect (*0 = negative; 100 = positive*) towards chemicals with 95% confidence intervals by groups.
* indicates significance at p < .01
** indicates significance at p < .001
n.s. indicates significance at p > .05 (not significant).

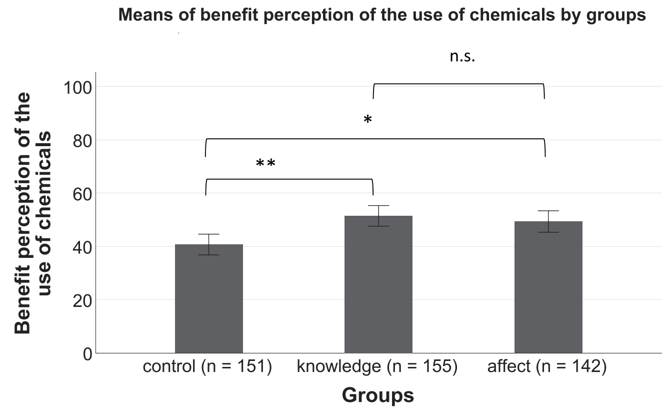

Fig. 5. Benefit perception of the use of chemicals with 95% confidence intervals by groups.
* indicates significance at p < .01
** indicates significance at p < .001
n.s. indicates significance at p > .05 (not significant).

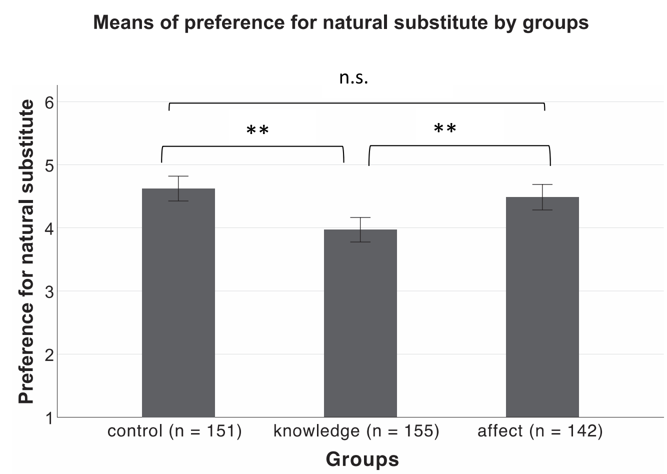

Fig. 6. Preference for natural substitutes in consumer products with 95% confidence intervals by groups.
** indicates significance at p < .001
n.s. indicates significance at p > .05 (not significant).

4. Discussion

Different communication strategies to reduce chemophobia were examined. On the one hand, the informational approach increased peoples' knowledge of basic toxicological principles, decreased chemophobia, increased benefit perception of the use of chemicals, and lowered preference for natural substitutes in consumer products. However, the affect-based approach only increased positive affect and benefit perception of the use of chemicals.

The informational approach successfully reduced chemophobia, which confirms the established association of lower risk perception and fear of chemicals with a better understanding of toxicological principles (Bearth et al., 2016; Bearth et al., 2019; Bredahl et al., 1998; Entine, 2011; Royal Society of Chemistry, 2015; Saleh et al., 2019; Siegrist and Bearth, 2019). Literature shows that knowledge about a technology does not necessarily lead to a lower risk perception or greater acceptance of that technology (Connor and Siegrist, 2010; Jobin et al., 2019; Renn, 2006; Wallquist et al., 2010). However, this seems to not be the case with chemicals. First and foremost, the information provided in the present study specifically addresses existing misconceptions and concerns regarding chemicals that have been identified and related to chemophobia in previous mixed-method studies (Bearth et al., 2019;

Saleh et al., 2019). It did not convey general knowledge about chemicals (e.g., types of hazardous chemicals, chemical reactions) that laypeople might already be familiar with or might be irrelevant to their perceptions. It also did not include benefit-related information; although, it did improve people's benefit perception of the use of chemicals. The rating of the informational video as interesting and useful also supports the theory that the information provided was relevant for the participants to evaluate the risks and benefits of chemicals. Therefore, the informational approach conveyed relevant knowledge in a simple and accessible way (i.e., in the form of a video).

The affect-based approach increased the salience of the benefits of the use of chemicals, leading to a more positive affect and a higher benefit perception of the use of chemicals. However, it did not reduce chemophobia. According to the quality evaluations for the videos, the affect approach video was not as useful or interesting as the informational approach video. Therefore, the benefits of chemicals highlighted in this approach could have been irrelevant to laypeople with high levels of chemophobia. People's perceptions of the benefits of a technology, as well as chemicals, might differ depending on their applications (Siegrist, 2003; Siegrist et al., 2008). Similarly, the use of synthetic chemicals in different products and technologies (e.g., medicine, food, water, electronics) might not all be perceived as equally beneficial and, thus, could explain the preference for natural chemicals by people exhibiting chemophobia. For instance, chemical-containing products that are ingested by people (e.g., food, water, medicine) might be more strongly affected by chemophobia than other consumer products (e.g., cell phones, cars), It might be more important to clarify in which domains (e.g., medical, technological, food) the use of synthetic chemicals is considered beneficial or risky to people, to better address the stigma associated with particular domains.

To reduce chemophobia, establishing an understanding of basic toxicological principles might be a more sustainable approach than a purely affect-based one. In fact, there already are communication efforts using different media channels (e.g., podcasts, videos, websites) to disseminate knowledge about chemicals and basic toxicological principles among the public. However, to our knowledge, their success has not been evaluated systematically (Hartings and Fahy, 2011; Royal Society of Chemistry, 2015). These communication efforts focus on transferring an understanding of the dose-response relationship, the composition of natural entities that can in fact be presented as chemicals (e.g., food perceived to be natural, such as a banana), and explaining that the origin of a chemical (i.e., natural origin or man-made) is not an indicator of its toxicity. These messages aim at addressing peoples' misconceptions and instrumental beliefs (i.e., natural chemicals are safer and healthier than synthetic chemicals) that might be guiding preference for natural chemicals and leading people to reject or avoid potentially irreplaceable synthetic chemical-containing products or innovations (e.g., vaccines). The findings of this study show that communication efforts focusing on the knowledge of basic toxicological principles can be effective in suppressing these instrumental beliefs. This, in turn, can limit chemophobia and the preference for natural substitutes in products. Moreover, Meier et al. (2019) also recently revealed that informational messages targeting laypeople's overestimations of the safety of natural chemicals could mitigate preference for chemicals of natural origin in medications. This could have implications for peoples' adherence to prescribed conventional medications.

Communicating basic toxicological principles to the public may be a challenging and difficult task for risk communicators not familiar with the subject. Toxicologists, however, are suitable for the role of risk communicators (Chalupa and Nesmerak, 2019; Hartings and Fahy, 2011; Monro, 2001; Wallace, 2011). For this, understanding how to foster and maintain public trust in scientists is necessary as high trust in the source of information and the messages relayed can ensure effective public outreach and knowledge dissemination (Breakwell, 2000; Siegrist et al., 2000). Another challenge arises when people unconvinced by the information provided, due to ideational beliefs, focus on the inherent and moral superiority of natural entities (Li and Chapman, 2012; Meier and Lappas, 2016; Rozin et al., 2004; Scott et al., 2016). There might be a need to investigate what influences ideational beliefs to know how these beliefs can be addressed to ensure a consistent decrease in chemophobia and increase in informed decision-making. Such challenges could be resolved by including toxicology as part of school curriculums.

In terms of limitations, the implications of long-term information retention and impact on perceptions of chemicals and chemophobia cannot be derived due to the design of the present study. Furthermore, preferences for natural substitutes in consumer products were self-reported by participants and it is unclear whether these preferences will be transferred into real life consumer decisions. Future research should focus on the evaluations of the long-term effects of knowledge provision on chemophobia and preference for natural substitutes in consumer products in a real-life setting. It might also be of interest to evaluate whether other related knowledge would have an impact on peoples' chemophobia and preferences for natural products (e.g., knowledge of the distinction between hazard and risk, knowledge of chemicals' risk assessment process). Previous research suggests that knowledge about the risk assessment process impacts people's risk perception of food additives (Bearth et al., 2014). In addition, chemophobia was not measured before exposing the participants to the videos, which does not allow for a comparison of the change in chemophobia levels within groups. Thus, future research should consider focusing on the change in chemophobia within individuals. Finally, another limitation is that younger people were under-represented in the sample. Using representative samples of Swiss, as well as other populations, to investigate the impact of the informational and affect-based strategies can help determine which approaches yield better results for different cultures and generations.

5. Conclusion

The present experimental study provides a better understanding of chemophobia and related factors, and offers insight into potentially effective communication approaches to mitigate chemophobia. Communicating information on basic toxicological principles in a simplified and accessible way might be a promising method to inform the public. Moreover, the negative stigma associated with chemicals might be difficult to address using only affective messages focusing on the benefits of chemicals for individuals and society. However, basic toxicological principles can be fundamentally taught in schools or disseminated by toxicologists and scientists who are trusted by the public to reduce chemophobia.

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CRediT authorship contribution statement

Rita Saleh: Formal analysis, Data curation, Writing - original draft. **Angela Bearth:** Supervision, Project administration, Formal analysis. **Michael Siegrist:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

This appendix contains information about the content of the videos used in the present study titled “Addressing Chemophobia: Informational versus affect-based approaches”. Links redirecting to the videos are also provided in this document.

“Knowledge” group

Text of the informational video regarding the basic toxicological principles viewed by the “knowledge” group

Chemical substances are everywhere, in living creatures, in the environment and in consumer products like food, medicine, cosmetics and cleaning products. It is therefore impossible to lead a life free of chemicals.

In fact, if we look at what a strawberry or egg is composed of, we get a long list of chemical substances, which we probably cannot pronounce or understand. But we can see that this strawberry and egg contain natural chemical substances. Hence, natural products contain also chemical substances.

Further, it doesn't matter whether the chemical substances are natural or synthetic, for natural chemicals and their synthetic counterparts have the same chemical identity. Let's take vitamin C as an example, which we find naturally in oranges but we can also buy in the form of tablets that are produced in laboratories. The chemical structure of vitamin C in the orange and the tablet are exactly the same. The vitamin C of the orange and of the tablet will have the same function and effects on the human body.

But natural chemical substances are often seen to be safe and healthy, while synthetic chemical substances are often seen as dangerous. But natural chemical substances are not inevitably safe and synthetic chemical substances are not inevitably harmful. Whether a chemical substance is natural or synthetic cannot tell us how dangerous it is.

In fact, every chemical substance, whether it synthetic or natural, can be toxic, when exposed to a certain dose. It is the dose that makes the chemical substance poisonous.

Let's take the example of sodium thiopental. Sodium thiopental is a synthetic chemical substance that was used in lethal injections in prisons the past. But what does an apple have in common with sodium thiopental? The apple seeds contain amygdalin, which has approximately the same toxicity as sodium thiopental.

Both, apple seeds and sodium thiopental can be toxic, if a person is exposed to a quantity of 1000 mg/kg of his bodyweight. But of course, there are such few seeds in an apple that they are not toxic at the amount present in an apple.

Link to view video: https://www.youtube.com/watch?v=ySBokHfTeQA&feature=youtu.be.

“Control” group

Text of the control video regarding black holes viewed by the “control” group

Black holes are objects that exist throughout the universe and possibly in all galaxies. Black holes are extremely dense, which is why their gravitation attracts everything that comes close by. Not even light can escape its grasp.

The most common black holes form when a massive star is wiped out in a big explosion and their dense core is left behind. If this core is heavier than a certain mass, the gravitational force exceeds all other forces, so that the core collapses and a new black hole is created.

Such objects can grow by swallowing material in their vicinity, such as gas, stars and even other black holes, or when two galaxies merge together. The most massive, so-called supermassive black holes, are probably in the centre of almost every galaxy, including our own.

Black holes do not emit any radiation themselves, or at least not nearly enough that it could be captured by a telescope. Therefore, the behavior and emission of material around it is observed instead, from radio to visible light up to X-rays. Since the shadow of the supermassive black hole is extremely small, it could not be observed directly until recently.

This is the picture that astronomers have taken recently of a black hole. What can be seen on this picture is indeed the shadow of a supermassive black hole in the galaxy M87.

The glowing gas surrounds the black hole, which appears as a dark circle in the middle. The gravitational pull of the black hole superheats the gas making it radiate. The colours in the picture were added by the astronomers, because the detected radiations where not visible for the naked eye. The yellow shades represent the most intensive radiations, while red depicts the less intensive radiations and black represents few or no radiations.

Why did the astronomers take a picture of a black hole in a galaxy far away, instead of one in our own galaxy?

One of the main reasons is, that the black hole in our galaxy is much smaller than the one in galaxy M87. Therefore, the material rotates much faster around the black hole in our galaxy, which would have blurred the image.

Link to view video: https://www.youtube.com/watch?v=g7P-Ipw8w5w&feature=youtu.be.

“Affect” group

Link to the affect-based appeal video regarding the benefits of the use of chemicals viewed by the “affect” group

https://www.youtube.com/watch?v=iqUpNf5dAjQ&feature=youtu.be.

This video was taken from the original video published by UNESCO in 2011 celebrating chemistry. The source of this video was revealed to the respondents of the “affect” group at the end of the experiment.

References

Alhakami, A., Slovic, P., 1994. A psychological study of the inverse relationship between perceived risk and perceived benefit. Risk Anal. 14 (6), 1085–1096. https://doi.org/10.1111/j.1539-6924.1994.tb00080.x.

Apaolaza, V., Hartmann, P., Lopez, C., Barrutia, J.M., Echebarria, C., 2014. Natural ingredients claim's halo effect on hedonic sensory experiences of perfumes. Food Qual. Prefer. 36, 81–86. https://doi.org/10.1016/j.foodqual.2014.03.004.

Asioli, D., Aschemann-Witzel, J., Caputo, V., Vecchio, R., Annunziata, A., Naes, T., Varela, P., 2017. Making sense of the "clean label" trends: a review of consumer food choice behavior and discussion of industry implications. Food Res. Int. 99, 58–71. https://doi.org/10.1016/j.foodres.2017.07.022.

Bearth, A., Cousin, M., Siegrist, M., 2014. The consumer's perception of artificial food additives: influences on acceptance, risk and benefit perceptions. Food Qual. Prefer. 38, 14–23. https://doi.org/10.1016/j.foodqual.2014.05.008.

Bearth, A., Cousin, M., Siegrist, M., 2016. The Dose Makes the Poison": informing consumers about the scientific risk assessment of food additives. Risk Anal. 36 (1), 130–144. https://doi.org/10.1111/risa.12410.

Bearth, A., Miesler, L., Siegrist, M., 2017. Consumers' risk perception of household cleaning and washing products. Risk Anal. 37 (4), 647–660. https://doi.org/10.1111/risa.12635.

Bearth, A., Saleh, R., Siegrist, M., 2019. Lay-people's knowledge about toxicology and its principles in eight European countries. Food Chem. Toxicol. 131https://doi.org/10.1016/j.fct.2019.06.007. 110560.

Breakwell, G.M., 2000. Risk communication: factors affecting impact. Br. Med. Bull. 56 (1), 110–120.

Bredahl, L., Grunert, K., Frewer, L., 1998. Consumer attitudes and decision-making with regard to genetically engineered food products – a review of the literature and a presentation of models for future research. J. Consum. Pol. 21, 251–277.

Cattell, R., 1966. The scree test for the number of factors. Multivariate Behav. Res. 1 (2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10.

Chalupa, R., Nesmerak, K., 2014. Chemophobia, public image of chemistry and what is to Be done. Chem. Listy 108 (10), 995–1000.

Chalupa, R., Nesmerak, K., 2018. Analytical chemistry as a tool for suppressing chemophobia: an introduction to the 5E-principle. Monatsh. Chem. 149 (9), 1527–1534. https://doi.org/10.1007/s00706-018-2224-9.

Chalupa, R., Nesmerak, K., 2019. Chelation as a metaphor for the effective fight against chemophobia. Monatsh. Chem. 150 (9), 1585–1592. https://doi.org/10.1007/s00706-019-02453-z.

Chermahini, S., Majid, F., Sarmidi, M., 2011. Cosmeceutical value of herbal extracts as natural ingredients and novel technologies in anti-aging. J. Med. Plants Res. 5 (14), 3074–3077.

Cohen, J., 1988. In: Hillsdale, N.J. (Ed.), Statistical Power Analysis for the Behavioral Sciences, second ed. L. Erlbaum Associates.

Connor, M., Siegrist, M., 2010. Factors influencing people's acceptance of gene technology: the role of knowledge, health expectations, naturalness, and social trust. Sci. Commun. 32 (4), 514–538. https://doi.org/10.1177/1075547009358919.

Cortina, J.M., Nouri, H., 2000. Effect Size for ANOVA Designs. Sage Publications, Thousand Oaks, Calif.

Dickson-Spillmann, M., Siegrist, M., Keller, C., 2011. Attitudes toward chemicals are associated with preference for natural food. Food Qual. Prefer. 22 (1), 149–156. https://doi.org/10.1016/j.foodqual.2010.09.001.

Entine, J., 2011. Scared to Death: How Chemophobia Threatens Public Health. American Council on Science and Health, New York, New York, pp. 10023–15860.

Finucane, M., Alhakami, A., Slovic, P., Johnson, S., 2000. The affect heuristic in judgments of risks and benefits. J. Behav. Decis. Making 13 (1), 1–17. https://doi.org/10.1002/(Sici)1099-0771(200001/03)13:1<1::Aid-Bdm333>3.0.Co;2-S.

Francl, M., 2013. How to counteract chemophobia. Nat. Chem. 5 (6), 439–440. https://doi.org/10.1038/nchem.1661.

Gigerenzer, G., Gaissmaier, W., 2011. Heuristic decision making. Annu. Rev. Psychol. 62, 451–482. https://doi.org/10.1146/annurev-psych-120709-145346.

Gribble, G.W., 2013. Food chemistry and chemophobia. Food Secur. 5 (2), 177–187. https://doi.org/10.1007/s12571-013-0251-2.

Hartings, M.R., Fahy, D., 2011. Communicating chemistry for public engagement. Nat. Chem. 3 (9), 674–677. https://doi.org/10.1038/nchem.1094.

Ibm Corp, 2017. IBM SPSS Statistics for Windows. IBM Corp, Armonk, NY Version 25.0.

Iversen, G.R., Norpoth, H., 1987. Analysis of Variance, second ed. Sage Publications, Newbury Park.

Jobin, M., Visschers, V.H.M., van Vliet, O.P.R., Arvai, J., Siegrist, M., 2019. Affect or information? Examining drivers of public preferences of future energy portfolios in Switzerland. Energy Res. Soc. Sci. 52, 20–29. https://doi.org/10.1016/j.erss.2019.01.016.

Kauffman, G.B., 1989. The origins and history of chemophobia. Abstr. Pap. Am. Chem. Soc. 198, 16–Ched.

King, J., Slovic, P., 2014. The affect heuristic in early judgments of product innovations. J. Consum. Behav. 13 (6), 411–428. https://doi.org/10.1002/cb.1491.

Kraus, N., Malmfors, T., Slovic, P., 1992. Intuitive toxicology - expert and lay judgments of chemical risks. Risk Anal. 12 (2), 215–232. https://doi.org/10.1111/j.1539-6924.1992.tb00669.x.

Li, M., Chapman, G.B., 2012. Why do people like natural? Instrumental and ideational bases for the naturalness preference. J. Appl. Soc. Psychol. 42 (12), 2859–2878. https://doi.org/10.1111/j.1559-1816.2012.00964.x.

Lynch, N., Berry, D., 2007. Differences in perceived risks and benefits of herbal, over-the-counter conventional, and prescribed conventional, medicines, and the implications of this for the safe and effective use of herbal products. Compl. Ther. Med. 15 (2), 84–91. https://doi.org/10.1016/j.ctim.2006.06.007.

McKee, C., Bohannon, K., 2016. Exploring the reasons behind parental refusal of vaccines. J. Pediatr. Pharmacol. Therapeut. 21 (2), 104–109. https://doi.org/10.5863/1551-6776-21.2.104.

Meier, B.P., Dillard, A.J., Osorio, E., Lappas, C.M., 2019. A behavioral confirmation and reduction of the natural versus synthetic drug bias. Med. Decis. Making 39 (4), 359–369. https://doi.org/10.1177/0272989x19838527.

Meier, B.P., Lappas, C.M., 2016. The influence of safety, efficacy, and medical condition severity on natural versus synthetic drug preference. Med. Decis. Making 36 (8), 1011–1019. https://doi.org/10.1177/0272989x15621877.

Mertz, C., Slovic, P., Purchase, I., 1998. Judgments of chemical risks: comparisons among senior managers, toxicologists, and the public. Risk Anal. 18 (4), 391–404. https://doi.org/10.1111/j.1539-6924.1998.tb00353.x.

Michaelis, A., 1996. Stop - chemophobia. Interdiscipl. Sci. Rev. 21 (2), 130–139. https://doi.org/10.1179/isr.1996.21.2.130.

Monro, A., 2001. Toxicologists - come out and educate!. Trends Pharmacol. Sci. 22 (6), 325–327. https://doi.org/10.1016/S0165-6147(00)01715-6.

Principe, L., 2013. The Secrets of Alchemy. University of Chicago Press, Chicago.

Renn, O., 2006. Risk communication - consumers between information and irritation. J. Risk Res. 9 (8), 833–850. https://doi.org/10.1080/13669870601010938.

Ropeik, D., 2015. On the roots of, and solutions to, the persistent battle between "chemonoia" and rationalist denialism of the subjective nature of human cognition. Hum. Exp. Toxicol. 34 (12), 1272–1278. https://doi.org/10.1177/0960327115603592.

Ropeik, D., 2011. Risk perception in toxicology-Part I: moving beyond scientific instincts to understand risk perception. Toxicol. Sci. 121 (1), 1–6. https://doi.org/10.1093/toxsci/kfr048.

Ropeik, D., 2012. The Perception Gap: recognizing and managing the risks that arise when we get risk wrong. Food Chem. Toxicol. 50 (5), 1222–1225. https://doi.org/10.1016/j.fct.2012.02.015.

Royal Society of Chemistry, 2015. Public attitudes to chemistry: research report. Retrieved from. https://www.rsc.org/campaigning-outreach/campaigning/public-attitudes-chemistry/.

Rozin, P., 2005. The meaning of "natural": process more important than content. Psychol. Sci. 16 (8), 652–658. https://doi.org/10.1111/j.1467-9280.2005.01589.x.

Rozin, P., Fischler, C., Shields-Argeles, C., 2012. European and American perspectives on the meaning of natural. Appetite 59 (2), 448–455. https://doi.org/10.1016/j.appet.2012.06.001.

Rozin, P., Spranca, M., Krieger, Z., Neuhaus, R., Surillo, D., Swerdlin, A., Wood, K., 2004. Preference for natural: instrumental and ideational/moral motivations, and the contrast between foods and medicines. Appetite 43 (2), 147–154. https://doi.org/10.1016/j.appet.2004.03.005.

Saleh, R., Bearth, A., Siegrist, M., 2019. "Chemophobia" today: consumers' knowledge and perceptions of chemicals. Risk Anal. https://doi.org/10.1111/risa.13375.

Scott, S.E., Inbar, Y., Rozin, P., 2016. Evidence for absolute moral opposition to genetically modified food in the United States. Perspect. Psychol. Sci. 11 (3), 315–324. https://doi.org/10.1177/1745691615621275.

Shim, S., Seo, S., Lee, Y., Moon, G., Kim, M., Park, J., 2011. Consumers' knowledge and safety perceptions of food additives: evaluation on the effectiveness of transmitting information on preservatives. Food Contr. 22 (7), 1054–1060. https://doi.org/10.1016/j.foodcont.2011.01.001.

Siegrist, M., 2003. Perception of gene technology, and food risks: results of a survey in Switzerland. J. Risk Res. 6 (1), 45–60. https://doi.org/10.1080/1366987032000047798.

Siegrist, M., Bearth, A., 2019. Chemophobia in Europe and reasons for biased risk perceptions. Nat. Chem. 11 (12), 1071–1072. https://doi.org/10.1038/s41557-019-0377-8.

Siegrist, M., Cvetkovich, G., Roth, C., 2000. Salient value similarity, social trust, and risk/benefit perception. Risk Anal. 20 (3), 353–362.

Siegrist, M., Stampfli, N., Kastenholz, H., Keller, C., 2008. Perceived risks and perceived benefits of different nanotechnology foods and nanotechnology food packaging. Appetite 51 (2), 283–290. https://doi.org/10.1016/j.appet.2008.02.020.

Siegrist, M., Sutterlin, B., 2014. Human and nature-caused hazards: the affect heuristic causes biased decisions. Risk Anal. 34 (8), 1482–1494. https://doi.org/10.1111/risa.12179.

Slovic, P., 1987. Perception of risk. Science 236 (4799), 280–285.

Slovic, P., Finucane, M., Peters, E., MacGregor, D., 2002. Rational actors or rational fools: implications of the affect heuristic for behavioral economics. J. Soc. Econ. 31, 329–342.

Slovic, P., Finucane, M., Peters, E., MacGregor, D., 2004. Risk as analysis and risk as feelings: some thoughts about affect, reason, risk, and rationality. Risk Anal. 24 (2), 311–322. https://doi.org/10.1111/j.0272-4332.2004.00433.x.

Slovic, P., Malmfors, T., Krewski, D., Mertz, C., Neil, N., Bartlett, S., 1995. Intuitive toxicology .2. Expert and lay judgments of chemical risks in Canada. Risk Anal. 15 (6), 661–675. https://doi.org/10.1111/j.1539-6924.1995.tb01338.x.

Slovic, P., Malmfors, T., Mertz, C., Neil, N., Purchase, I., 1997. Evaluating chemical risks: results of a survey of the British Toxicology Society. Hum. Exp. Toxicol. 16 (6), 289–304. https://doi.org/10.1177/096032719701600601.

Slovic, P., Peters, E., Finucane, M.L., Macgregor, D.G., 2005. Affect, risk, and decision making. Health Psychol. 24 (4S), S35–S40. https://doi.org/10.1037/0278-6133.24.4.S35.

Streiner, D.L., 2003. Starting at the beginning: an introduction to coefficient alpha and internal consistency. J. Pers. Assess. 80 (1), 99–103. https://doi.org/10.1207/S15327752JPA8001_18.

Tableau Software Inc, 2003. Tableau Desktop (version 2018.1.10). Retrieved from. https://www.tableau.com/products/desktop.

Ugoni, A., Walker, B.F., 1995. The Chi square test: an introduction. COMSIG Rev. 4 (3), 61–64.

UNESCO, 2011. Chemistry: all about you. Publication no. https://www.youtube.com/watch?v=xN-uZKPUgYA.

Wallace, H., 2011. Risk perception in toxicology-part II: toxicology must be the solution not the problem. Toxicol. Sci. 121 (1), 7–10. https://doi.org/10.1093/toxsci/kfr049.

Wallquist, L., Visschers, V.H., Siegrist, M., 2010. Impact of knowledge and misconceptions on benefit and risk perception of CCS. Environ. Sci. Technol. 44 (17), 6557–6562. https://doi.org/10.1021/es1005412.

Williams, D.J., Noyes, J.M., 2007. How does our perception of risk influence decision-making? Implications for the design of risk information. Theor. Issues Ergon. Sci. 8 (1), 1–35. https://doi.org/10.1080/14639220500484419.

Winter, C.K., Katz, J.M., 2011. Dietary exposure to pesticide residues from commodities alleged to contain the highest contamination levels. J. Toxicol. https://doi.org/10.1155/2011/589674.