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"The Dose Makes the Poison": Informing Consumers About the Scientific Risk Assessment of Food Additives

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Intensive risk assessment is required before the approval of food additives. During this process, based on the toxicological principle of "the dose makes the poison," maximum usage doses are assessed. However, most consumers are not aware of these efforts to ensure the safety of food additives and are therefore sceptical, even though food additives bring certain benefits to consumers. This study investigated the effect of a short video, which explains the scientific risk assessment and regulation of food additives, on consumers' perceptions and acceptance of food additives. The primary goal of this study was to inform consumers and enable them to construct their own risk-benefit assessment and make informed decisions about food additives. The secondary goal was to investigate whether people have different perceptions of food additives of artificial (i.e., aspartame) or natural origin (i.e., steviolglycoside). To attain these research goals, an online experiment was conducted on 185 Swiss consumers. Participants were randomly assigned to either the experimental group, which was shown a video about the scientific risk assessment of food additives, or the control group, which was shown a video about a topic irrelevant to the study. After watching the video, the respondents knew significantly more, expressed more positive thoughts and feelings, had less risk perception, and more acceptance than prior to watching the video. Thus, it appears that informing consumers about complex food safety topics, such as the scientific risk assessment of food additives, is possible, and using a carefully developed information video is a successful strategy for informing consumers.

KEY WORDS: Aspartame; communication; knowledge; risk assessment; steviolglycoside

1. INTRODUCTION

In their article, Kraus *et al.*[1] coined the term intuitive toxicology: "Human beings have always been 'intuitive toxicologists', relying on their sense of sight, taste, and smell to detect harmful or unsafe food, water, and air" (p. 215). According to the authors, because of the inadequacies of this intuitive toxicology, the sciences of toxicology and risk assessment were developed to test the safety of chemicals. Chemicals used in foods, such as food additives, undergo intensive scientific risk assessment, and maximum usage doses are set before their approval for usage in foods.[2] Despite some controversy among experts in regards to the uncertainty linked to this risk assessment, experts generally agree on the safety of these procedures and stress the major benefits associated with the use of food additives.[2–4] Most laypeople lack the necessary background information to retrace this step of risk-and-benefit analysis, and other factors, such as heuristics and their trust in regulators or (potentially biased) information sources, may influence their perception and acceptance of food additives.[5,6] Some consumers are worried about food additives in their food

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and call for more information about this topic.[6,7] Specifically, food additives of artificial origin arouse suspicion in some consumers.[8,9] The perception of the general superiority of natural products to artificial products appears to be deeply rooted, and is even used by the food industry for marketing purposes in the practice of "clean labeling."[10] Clean labeling is the practice of replacing artificial food additives with food additives of natural origin to label the product "free of artificial additives."[10] In light of the ideal of the "informed consumer," informing interested consumers about the scientific risk assessment, risk-benefit analyses, and regulation of food additives is important. Another important issue might be that, if consumers focus on minor potential food risks, such as food additives, they may disregard information about more important food risks, such as microbial contamination.[11,12] Thus, the primary goal of this study was to investigate whether carefully designed information about food additives' risk assessment process has the capacity to increase people's knowledge and change their perceptions of food additives. The secondary goal was to investigate whether and in what ways food additives of natural or artificial origin are perceived differently. Subsequently, these two research goals are discussed in more detail.

2. THEORETICAL BACKGROUND

2.1. Scientific Risk Assessment and Regulation of Food Additives

As stated in Section 1, a long process of scientific risk assessment is required before the approval of food additives.[2] In Europe, a number of studies are mandatory to be conducted before a food additive can be considered, such as acute, chronic, reproductive, and developmental toxicity studies.[2] Approved food additives need to be observed and, if necessary, reevaluated. Another important part of the scientific risk assessment of food additives is linked to the notion of the dose-response relationship: the determination of the acceptable daily intake (ADI). The ADI is the amount of a certain food additive that can be consumed daily over a lifetime without causing any health effects.[2] This amount is derived on the basis of the lowest no-observed-adverse-effect level (NOAEL) from toxicity studies and a safety factor of usually 100, by which the NOAEL is divided.[2] The safety factor considers that the NOAEL is based on animal studies and that there are interindividual differences between consumers. Furthermore, the projected consumption and targeted consumers of a certain food in which the additive will be used are taken into account during the risk assessment process.[2] Despite this intensive scientific risk assessment, deciding on the absolute safety of a certain food additive is not possible, as scientific practice is usually linked to a certain amount of uncertainty.[2,3] However, experts justify the use of food additives by weighing up this uncertainty with the benefits associated with the use of food additives (e.g., food quality and variety, higher shelf life, convenience).

2.2. What is the Consumers' Point of View?

A previous study investigating Swiss consumers' perception of artificial sweeteners and food colors[6] found that consumers' acceptance of these food additives is related to their risk and benefit perceptions, trust in regulators, knowledge about regulation, and their preference for natural food. Furthermore, people who exhibited little knowledge about the regulation of food additives expressed higher risk perceptions and lower acceptance than people with more knowledge.[5,6,13] Therefore, informing consumers about the scientific risk assessment, dose-response relationship, and regulation of food additives may influence their risk perception and acceptance of food additives. Information may also influence benefit perception, as laypeople do not assess risks and benefits separately.[14–16] Moreover, independent of perceptions and acceptance, which could be classified as cognitive aspects, information may change whether people think or feel more positively or negatively about food additives, which is more of an affective aspect.

Unfortunately, however, informing consumers about the scientific risk assessment of food additives is not an easy task. Risk assessment comprises a number of complex steps that involve uncertainty and require a basic understanding of toxicology and the dose-response relationship. Studies show that laypeople have difficulty understanding the toxicological concept of "the dose makes the poison."[1,17] Furthermore, it has been shown that people exhibit a "negativity bias" related to risk perceptions; that is, people have more confidence in significant study results than in results that do not find an effect.[18,19] Therefore, consumers are more likely to believe the results of studies that find adverse effects of a certain food additive than those that declare the safety of a food additive. This negativity bias further

complicates the communication of the safety of food additives.

Due to the strains mentioned in the previous section, it is especially important that risk communication material is carefully designed and evaluated before using it for public communication. There are methodologies to develop communication material that considers the most important information while keeping in mind laypeople's points of view and potential misconceptions. The mental models approach (MMA)[20] is a method used to create risk communication material. It has been adopted for the development of communication material for a variety of risks.[21–24] The method involves a series of five steps, from conducting expert (1) and laypeople interviews (2), to conducting a representative survey (3), and developing (4), and evaluating (5) the concrete communication material. The first three steps of the MMA have been presented elsewhere.[6] This study's first research goal represents the final step: the evaluation of the developed information material. The following hypotheses were investigated:

- Information provision will *increase* knowledge of regulation.
- Information provision will *increase* positive thoughts and feelings about the sweetener in question.
- Information provision will *reduce* risk perception and *increase* benefit perception and acceptance.

Over and above these hypotheses, the consumers' subjective evaluation of the information form and content was of interest in this study.

2.3. Natural Versus Artificial Food Additives

An important aspect to consider is the perceived artificiality or naturalness of a certain food additive. Despite the fact that no differentiation exists between additives of artificial and natural origin in scientific risk assessment, laypeople regard the latter with less suspicion.[25–27] Moreover, the preference for "natural foods," a notion frequently associated with having "no artificial additives," is well documented in the literature, most prominently in the work of Rozin.[8,9,28] Rozin explained the perceived importance of naturalness in foods with several instrumental and ideological beliefs and the concept of biophilia, which denotes the innate desire for experiencing our ancestral natural environment.[9] Furthermore, Rozin and colleagues investigated what destroys naturalness in foods and found that processing food, especially chemical processing, reduces its rated naturalness more than adding or subtracting content.[28] However, adding very small doses of unnatural substances, such as purified minerals, substantially reduces naturalness ratings.[28] This study's second research goal attempts to further this line of research by investigating whether consumers perceive two different food additives, one of natural and one of artificial origin, differently. Thus, two different sweeteners were investigated: the artificially manufactured aspartame and the sweetener steviolglycoside, which is extracted from leaves of the *Stevia rebaudiana* plant. According to Rozin's research, aspartame is expected to be considered less natural than steviolglycoside, which is associated with a plant. Consequently, steviolglycoside is expected to be considered more positively than aspartame because of the so-called naturalness halo.[9,29] For this secondary research goal, the following hypotheses were stated:

- A sweetener of natural origin will *evoke more* positive thoughts and feelings than a sweetener of artificial origin.
- A sweetener of natural origin will *evoke less* risk perception and *more* benefit perception and acceptance than a sweetener of artificial origin.

3. METHOD

3.1. Study Design

Participants were recruited through an online panel from among the German-speaking population in Switzerland. Recruitment was supplemented by advertising the study through a mailing list for psychology students. Potential participants were sent an email inviting them to participate in an online survey about sweeteners in drinks and foods. As an incentive to participate, a summary of the most interesting results of the study was offered. The experiment had a 2 (questionnaire about aspartame or steviolglycoside) x 2 (experimental or control group) x 2 (before or after the information provision) design. After giving their informed consent, the participants were randomly assigned to one of the four groups. The two sweeteners were introduced to the participants before assessing the participants' baseline

variables with the following text (steviolglycoside version in parentheses):

> *Sweeteners are food additives. They serve as substitutes for sugar and are either manufactured artificially or extracted naturally. In contrast to sugar, they have a much stronger sweetening power, but have no or hardly any calories. The present questionnaire is about the sweetener aspartame (steviolglycoside). Aspartame was accidently discovered by a chemist and is considered an artificially manufactured sweetener (Steviolglycoside is extracted from the leaves of the Stevia plant and is considered a naturally extracted sweetener). Aspartame (Steviolglycoside) is used to sweeten soft drinks, diet products, sweets and chewing gum, milk products, and coffee and tea.*

After that introductory part, baseline thoughts and feelings, risk and benefit perception, acceptance, trust in regulators, knowledge of regulation, and naturalness perception were assessed. Subsequently, the participants from the experimental groups were shown a three-minute motion graph video explaining the process of scientific risk assessment and regulation of aspartame or steviolglycoside, respectively. The video introduced the participants to the main risk assessment studies (e.g., toxicokinetics, toxicity, cancerogenicity estimated consumption and consumer), the dose-response relationship, and the process of determining the NOAEL and ADI (cf. Appendix). The complex topic of scientific risk assessment and regulation of food additives was carefully discussed and simplified. The participants from the control group were also shown a three-minute motion graph video, but this video was about an issue that is unrelated to the study topic (Human Development Index). Care was taken to make the control video similar in length, difficulty, complexity, and design to the experimental video. No source of the video was indicated. After watching the video, participants were asked whether they were able to watch the video with sound or whether they encountered any technical difficulties. The participants who indicated encountering technical difficulties ($n = 15$) were directed to the end of the survey and excluded from the final sample. The remaining participants were invited to evaluate the video, which was followed by the assessment of the follow-up variables, the preference for natural foods, sweetener consumption, and sociodemographics. Participants of the two control groups were explained the purpose of the study at the end of the questionnaire and were shown the experimental video.

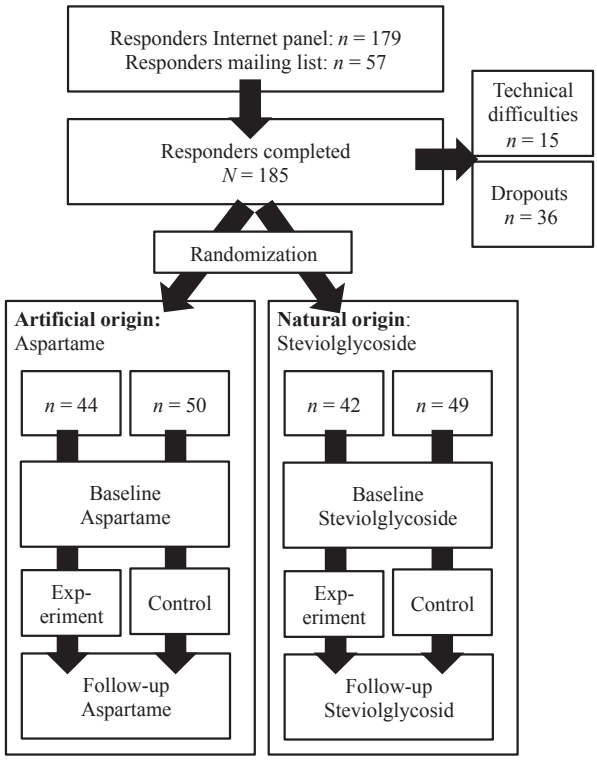

Fig. 1. Study design.

3.2. Study Participants

Fig. 1 presents an overview of the study design, the number of participants in each group, and the number of people who did not respond or dropped out during the study.

A total of 35 participants (15%) filled out less than half of the online questionnaire and were thus excluded from the final sample. One person had to be excluded because he had filled out the questionnaire in less than four minutes (including the three minutes required for watching the video) and chose the same response field throughout the questionnaire. The drop-out rate did not differ significantly among the four groups, $\chi^2(3) = 1.40, p = .706$. The final sample comprised 185 participants (52% males, $M_{age} = 54$, $SD_{age} = 17$, range: 20 to 90 years). In the sample, 86 participants were in the experimental condition (aspartame: $n = 44$ people, steviolglycoside: $n = 42$) and 99 participants were in the control condition (aspartame: $n = 50$, steviolglycoside: $n = 49$). Table I shows the sociodemographics of the four groups. According to χ^2-tests the four groups did not differ significantly in their distribution of men and women ($\chi^2(3) = 2.99, p = .393$) or educational group ($\chi^2(6)$

Table I. Sociodemographics by Group

			Aspartame		Steviolglycoside	
		Total	Experiment	Control	Experiment	Control
Gender	Male	97	25	26	25	21
	Female	88	19	24	17	28
Education	Low	50	9	12	12	17
	Middle	57	18	18	11	10
	High	78	17	20	19	22
Age	*M* (*SD*)	54.0 (17.3)	54.0 (17.7)	56.5 (18.9)	53.2 (17.2)	52.1 (15.6)

Note: M: Mean, *SD*: Standard deviation (range 20–90 years).

$= 6.25$, $p = .396$). The two-way ANOVA shows that the groups did not differ according to their mean age ($Fs < 1.03, ps > .311$). Similar to the result of the two-way ANOVAs of the means before the video, the experimental and control groups did not differ significantly before the video in any of the investigated variables ($Fs < 0.65$, $ps > .421$). In comparison to the Swiss population,[30] our sample is representative in terms of gender (49% males in 2012), but slightly older ($M_{CH} = 48$ in 2012) and better educated, as the majority of participants indicated a higher degree of education.

3.3. Materials

All included items were based on qualitative interviews and pretested in a preceding study.[6] All continuously scaled constructs exhibited a one-dimensional structure before and after the video and were built by taking the mean of the corresponding items. Sections 3.3.1 and 3.3.3 present the construction of the knowledge and sweetener consumption in more detail.

3.3.1. Knowledge of Regulation

The knowledge scale consisted of five correct and two incorrect statements and participants were asked to indicate whether they thought the statements were "true" or "false" or whether they did not know. For scale construction, correct responses were coded with 1, while incorrect and "do not know" responses were coded with 0. Subsequently, the achieved points in the seven items were summed up to obtain the final knowledge of regulation scale. Fig. 2 shows the seven knowledge statements.

3.3.2. Thoughts and Feelings, Risk and Benefit Perception, and Acceptance

The participants were asked with one item each whether their thoughts or feelings about aspartame/steviolglycoside were rather "negative" (1) or "positive" (9). As the two items were highly correlated before and after the video ($r = .90$ and $r = .92$, both $p < .001$), they were combined into one measure. Acceptance and risk and benefit perception were assessed with three items each. Table II presents these items, the response format, and the internal consistency coefficient. The first two items of the acceptance scale were reverse-coded items. The internal consistencies of the risk and benefit perception and acceptance of sweeteners scale were good or very good both before and after the video.

3.3.3. Trust in Regulators, Preference for Natural Foods, and Other Control Variables

A number of control variables were included, which were found to influence people's perceptions and acceptance of food additives.[6] Both participants' trust in regulators and their preference for natural foods were assessed with three items each, as shown in Table II. Both scales exhibited good or very good internal consistency. Trust was measured before the video, while natural preference was measured at the end of the questionnaire. The participants' sweetener consumption was assessed towards the end of the questionnaire by asking them to indicate how frequently they consumed the following four foods sweetened with sweeteners (not sugar): soft drinks (e.g., Diet Coke, Fanta Zero), sweetened coffee or tea (e.g., sweetened with Assugrin, Canderel), sugar-free sweets (e.g., sugar-free chewing gum or drops), and diet milk products (e.g.,

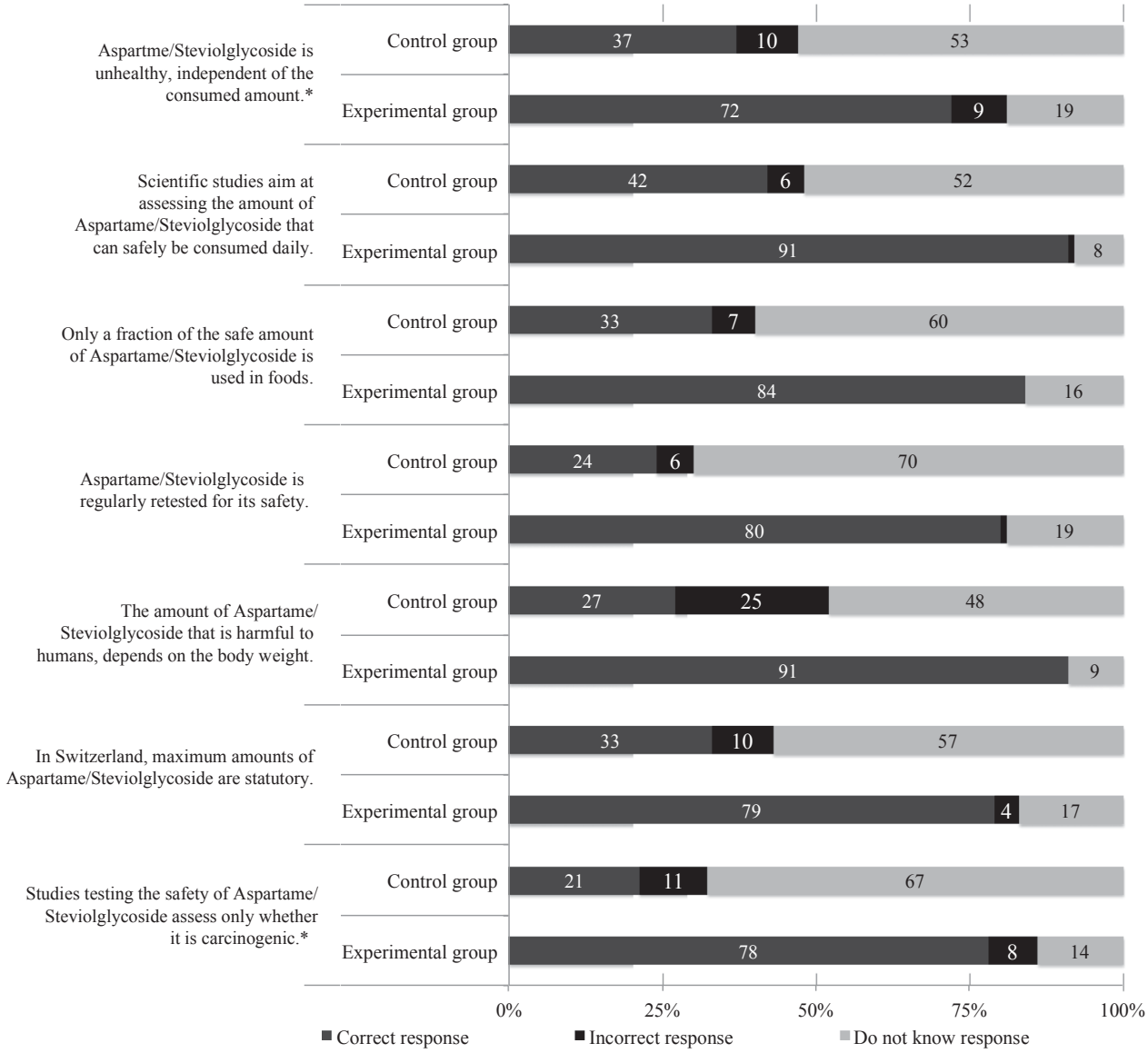

Fig. 2. Knowledge after watching the video (* incorrect statement; sweetener groups were combined because they did not differ substantially).

Weight Watchers yoghurt). The participants chose from the following answers: "daily" (4), "a few times per week" (3), "a few time per month" (2), "rarely" (1), "never" (0), and "I do not consume this food in general" (0). The total sweetener consumption was assessed by summing up the responses over all four foods. To determine whether the participants differentiated between the two sweeteners in terms of naturalness, they were asked to indicate whether they considered the sweetener in question to be "artificial" (1) or "natural" (9).

In a number of open and closed items, participants were asked to evaluate the videos. First, participants rated the viewed video subjectively according to the criteria of "understandable," "believable," "interesting," and "learnt something new through video" (1 = "do not agree at all" to 9 = "agree completely"). Second, the participants of the experimental groups were asked to indicate whether they considered the video to influence their attitude and feelings towards aspartame/steviolglycoside or their consumer behaviour (1 = "no influence at all"

Table II. Items and Scales: Ranges and Internal Consistency

	Before Video α	After Video α
Risk perception (1: do not agree at all to 9: agree completely)	.95	.93
I think that aspartame/steviolglycoside is harmful to health.		
I think that aspartame/steviolglycoside is unhealthy.		
I believe that aspartame/steviolglycoside is a risk for human health.		
Benefit perception (1: do not agree at all to 9: agree completely)	.80	.84
The use of aspartame/steviolgylcoside brings me benefits.		
The use of aspartame/steviolglycoside reduces unnecessary calories.		
I appreciate aspartame/steviolglycoside because it does not harm the teeth.		
Acceptance (1: do not agree at all to 9: agree completely)	.83	.80
I pass certain foods up because they contain aspartame/steviolglycoside.*		
It bothers me if my foods contains aspartame/steviolglycoside.*		
I can accept that certain foods contain aspartame/steviolglycoside.		
Trust in regulators (1: do not agree at all to 9: agree completely)	.95	–
I think that you can trust the regulators in general.		
I trust the regulators in terms of the licensing and control of aspartame/steviolglycoside in foods.		
I trust the regulators to ensure all steps are taken to protect consumer health.		
Preference for natural foods (1: do not agree at all to 9: agree completely)	.74	–
I pay attention during grocery shopping to ensure that the food I buy is as natural as possible.		
Natural food tastes better than other food.		
Natural food is better for my health.		

Note: *Reverse-coded item.

to 9 = "a big influence"). Lastly, in an open question, criticism and suggestions for improvements were collected.

3.4. Data Analysis

All data analyses were conducted with SPSS version 22.0.[31] The main analyses were evaluated by mixed ANOVAs and simple effect analyses for interaction effects of interest for our hypotheses. Pearson's correlations were also conducted, and two-tailed significant differences between correlations were analyzed with Fisher's Z-test.[32] Additional analyses were conducted using two-way ANOVAs, χ^2, and t-tests. Effect sizes η^2 were reported for the significant effects of the mixed ANOVAs.

4. RESULTS

The result section is grouped into three parts: 1) analysis of the success of the sweetener manipulation, the potential influences of the included control variables, and the relationships among the included variables before the video; 2) investigation of the experimental results presented separately for each included variable: knowledge, thoughts and feelings, risk and benefit perceptions, and acceptance; and 3) participants' subjective perception of the informational video.

4.1. Analysis of the Sweetener Manipulation, Control Variables, and Variable Interrelationships

To test the sweetener manipulation, we examined participants' naturalness perception of aspartame, which was introduced as an "artificially manufactured sweetener" and steviolglycoside, which was introduced as a "naturally extracted sweetener." Sweetener had a significant main effect on the naturalness perception before the video, $F(1, 181) = 103.42$, $p < .001$, $\eta^2 = .35$. Steviolglycoside was perceived as more natural ($M = 5.53$, $SD = 2.58$) than aspartame ($M = 2.26$, $SD = 1.69$). No main effect of condition or interaction effect was found between condition and sweetener (Fs < 0.26, $ps > .609$).

Three control variables, found in previous literature[6] to influence the risk and benefit perception and acceptance of sweeteners, were included in the study questionnaire: trust, preference for natural foods, and sweetener consumption. Thus, it was investigated whether the groups differed according

to these three control variables. No main or interaction effect was found for condition and sweetener on participants' trust in regulators ($Fs < 1.60$, $ps > .208$) or on sweetener consumption ($Fs < 1.93$, $ps > .167$). In all four groups, trust had a mean of $M = 6.40$ ($SD = 2.04$, range: 1 to 9), and sweetener consumption had a mean of $M = 3.72$ ($SD = 2.55$, range: 0 to 12). A significant main effect of condition was found on the preference for natural foods, $F(1, 181) = 4.87$, $p = .029$, $\eta^2 = .03$. The participants from the control groups ($M = 7.71$, $SD = 1.42$) expressed higher preferences for natural foods than participants from the experimental groups ($M = 7.22$, $SD = 1.62$). However, the difference is rather small according to the effect size. The main effect of sweetener and the interaction of the two variables were nonsignificant ($Fs < 3.08$, $ps > .081$).

Table III shows the Pearson's correlations of the constructs before the video grouped by sweetener. Significantly different correlations between the aspartame and the steviolglycoside groups according to Fisher's Z-test are indicated by the shading of the cells. A number of significant differences were found between the two sweeteners in studying the correlation coefficients before the video. Whereas trust in regulators was related to the participants' thoughts and feelings, risk perception, and acceptance of aspartame, these variables were less strongly related for steviolglycoside. Similar significant differences were found for the relationships between the preference for natural foods and the three variables mentioned above. Moreover, although sweetener consumption was significantly linked to the acceptance of aspartame, it is not linked to the acceptance of steviolglycoside. Risk perception and thoughts and feelings were more strongly linked for aspartame than for steviolglycoside, and while the naturalness perception of aspartame was significantly linked to the preference for natural foods, there was no significant correlation for steviolglycoside.

4.2. Effect of the Video on the Investigated Variables

Subsequently, the video's impact on participants' knowledge, thoughts and feelings, perceptions, and acceptance of sweeteners are investigated utilizing ANOVAs. The experimental design was a 2 (sweetener: aspartame or steviolglycoside) x 2 (condition: experimental or control group) x 2 (time point: before or after the video).

4.2.1. Participants' Knowledge Before and After the Video

Participants in the four groups did not differ significantly ($\chi^2(3) = 2.60$, $p = .458$) according to whether they had heard of aspartame or steviolglycoside before. About 70% of the participants knew the sweetener in question. According to a mixed ANOVA, there were significant main effects of condition and of time point and a significant interaction effect of time point and condition on knowledge. The other main and interaction effects were not significant. Table IV presents the knowledge means and standard deviations before and after the video, as well as the results for the mixed ANOVA. According to the subsequently conducted simple effect analysis of the interaction effect of time point and condition, time point significantly influenced the experimental groups' knowledge, $F(1, 183) = 443.23$, $p < .001$, but not the control groups' knowledge, $F(1, 183) = 0.06$, $p = .807$. Thus, the first hypothesis related to the effect of the information is accepted; the videos on the safety assessment of the sweeteners did increase knowledge in the experimental groups.

Fig. 2 shows the responses to the seven knowledge items after the video combined for the two experimental groups and the two control groups. The participants from the experimental groups exhibited less "do not know" responses (8 to 19%) than the control groups (48 to 67%). Incorrect responses were reduced in the experimental groups (0 to 9%) compared with the control groups (6 to 25%).

4.2.2. Participants' Thoughts and Feelings, Perceptions, and Acceptance Before and After the Video

For the participants' thoughts and feelings about either aspartame or steviolglycoside, there were significant main effects of sweetener and of time point and an interaction effect of time point and condition. The remaining effects were nonsignificant. Table IV exhibits the results of the mixed ANOVA, and means and standard deviations of participants' thoughts and feelings before and after the video. The participants expressed neither extremely positive nor extremely negative thoughts and feelings in relation to the two sweeteners. However, as predicted by the naturalness hypothesis and suggested by the main effect of sweetener, steviolglycoside was appraised slightly more positively than aspartame. Furthermore, simple

Table III. Pearson's Correlations Before Watching the Video for the Investigated Variables in the Aspartame and Steviolglycoside Groups

	Knowledge of Regulation	Thoughts and Feelings	Risk Perception	Benefit Perception	Acceptance	Trust	Preference for Natural Foods	Sweetener Consumption
Aspartame								
Knowledge of regulation	–							
Thoughts and feelings	0.23*	–						
Risk perception	–0.27**	–0.69**	–					
Benefit perception	0.25*	0.51**	–0.41**	–				
Acceptance	0.34**	0.70**	–0.70**	0.51**	–			
Trust in regulators	0.15	0.54**	–0.56**	0.33**	0.49**	–		
Preference for natural foods	–0.03	–0.28**	0.30**	–0.16	–0.41**	–0.29**	–	
Sweetener consumption	0.20*	0.50**	–0.31**	0.39**	0.53**	0.23*	–0.30**	–
Naturalness perception	0.06	0.42**	–0.33**	0.22*	0.36**	0.28**	–0.32**	0.27**
Steviolglycoside								
Knowledge of regulation	–							
Thoughts and feelings	0.29**	–						
Risk perception	–0.13	–0.49**	–					
Benefit perception	0.24*	0.61**	–0.34**	–				
Acceptance	0.13	0.62**	–0.57**	0.44**	–			
Trust in regulators	–0.01	0.14	–0.17	0.21*	0.23*	–		
Preference for natural foods	–0.03	0.09	–0.04	–0.06	–0.04	–0.22*	–	
Sweetener consumption	0.22*	0.29**	–0.14	0.37**	0.20	0.17	–0.34**	–
Naturalness perception	0.17	0.48**	–0.28**	0.42**	0.43**	0.11	0.12	0.17

Note: $^{**}p < 0.01$, $^{*}p < 0.05$. Significant differences ($p < 0.05$) in correlation coefficients between sweeteners highlighted by shading of the cell)

effect analyses of the interaction effect of time point and condition revealed that the thoughts and feelings of the experimental groups, $F(1, 183) = 32.15$, $p < .001$, were significantly affected by time point, but not the control groups' thoughts and feelings, $F(1, 183) = 2.86$, $p = .093$. Thus, the hypothesis related to the effect of the videos is accepted; the videos about the safety assessment of the sweeteners improved participants' appraisals of both sweeteners.

4.2.3. Participants' Perceptions and Acceptance Before and After the Video

Table IV shows the results of the mixed ANOVA, means, and standard deviations of the three variables, categorized by group and time point. For risk perception, there was a significant main effect of sweetener and an interaction effect of time point and condition. No other effects were significant. Generally, the main effect of sweetener and the means suggest that steviolglycoside is judged as less risky than aspartame. Hence, the hypothesis related to the risk perception and naturalness of the two sweeteners is accepted. Simple effect analysis of the significant interaction effect revealed that both experimental groups, $F(1, 183) = 11.79$, $p < .001$, and control groups, $F(1, 183) = 5.21$, $p = .024$, were affected by time point. While the experimental video significantly reduced risk perception in the experimental groups as hypothesized, the control video increased risk perception slightly, but significantly in the control groups.

For benefit perception, there was solely a significant main effect of sweetener and a marginally significant interaction effect of time point and sweetener. No other main or interaction effects were found significant. As suggested by the main effect of sweetener and as predicted by our hypothesis related to naturalness and benefit perception, steviolglycoside was judged to have more benefits than aspartame. However, the hypothesis that information provision increases benefit perception is rejected.

In terms of acceptance, there was a main effect of sweetener and an interaction effect of time point and condition. The remaining effects were nonsignificant. Overall, the participants who assessed steviolglycoside expressed more acceptance than those who assessed aspartame, thus confirming our naturalness hypothesis. Simple effect analyses of the significant interaction effect revealed that solely the experimental groups significantly changed their acceptance

Table IV. Variables of Interest by Condition, Sweetener, and Time Point: Results of 2×2×2 ANOVAS

	Before the Video *M* (*SD*)	After the Video *M* (*SD*)	Results of 2×2×2 ANOVA				
			Effects	*F*	df	*p*	η^2
Knowledge of regulation							
Aspartame			Time point	230.83	1,181	0.001	0.56
Experimental	2.14 (1.89)	5.73 (1.70)	Condition	44.55	1,181	0.001	0.20
Control	1.96 (1.74)	1.98 (1.91)	Sweetener	0.58	1,181	0.448	–
Steviolglycoside			Time point x condition	241.19	1,181	0.001	0.57
Experimental	1.88 (2.04)	5.76 (1.85)	Time point x sweetener	0.12	1,181	0.730	–
Control	2.51 (1.97)	2.41 (1.92)	Condition x sweetener	1.45	1,181	0.230	–
			Time point x condition x sweetener	0.72	1,181	0.398	–
Thoughts and feelings							
Aspartame			Time point	8.99	1,181	0.003	0.05
Experimental	4.07 (2.42)	4.85 (2.56)	Condition	1.42	1,181	0.234	–
Control	4.22 (2.24)	3.89 (2.26)	Sweetener	19.68	1,181	0.001	0.01
Steviolglycoside			Time point x condition	27.96	1,181	0.001	0.13
Experimental	5.37 (2.29)	6.33 (2.03)	Time point x sweetener	0.72	1,181	0.399	–
Control	5.57 (2.24)	5.42 (2.15)	Condition x sweetener	0.01	1,181	0.939	–
			Time point x condition x sweetener	0.00	1,181	0.994	–
Risk perception							
Aspartame			Time point	0.88	1,181	0.348	–
Experimental	4.84 (2.33)	4.17 (2.30)	Condition	1.54	1,181	0.217	–
Control	4.89 (2.35)	5.25 (2.27)	sweetener	19.44	1,181	0.001	0.10
Steviolglycoside			Time point x condition	16.30	1,181	0.001	0.08
Experimental	3.67 (1.83)	3.24 (1.89)	Time point x sweetener	0.17	1,181	0.680	–
Control	3.44 (1.75)	3.76 (1.75)	Condition x sweetener	0.53	1,181	.467	–
			Time point x condition x sweetener	0.39	1,181	0.533	–
Benefit perception							
Aspartame			Time point	0.08	1,181	0.777	–
Experimental	4.51 (2.39)	4.36 (2.47)	Condition	0.95	1,181	0.332	–
Control	4.14 (2.38)	3.91 (2.42)	Sweetener	11.83	1,181	0.001	0.06
Steviolglycoside			Time point x condition	0.78	1,181	0.378	–
Experimental	5.29 (1.74)	5.55 (1.87)	Time point x sweetener	3.72	1,181	0.055	–
Control	5.20 (2.17)	5.22 (2.13)	Condition x sweetener	0.10	1,181	0.757	–
			Time point x condition x sweetener	0.20	1,181	0.658	–
Acceptance							
Aspartame			Time point	0.92	1,181	0.339	–
Experimental	5.66 (2.63)	6.07 (2.53)	Condition	0.58	1,181	0.446	–
Control	5.73 (2.46)	5.57 (2.40)	Sweetener	9.30	1,181	0.003	0.05
Steviolglycoside			Time point x condition	5.53	1,181	0.020	0.03
Experimental	6.75 (1.91)	6.96 (1.86)	Time point x sweetener	0.16	1,181	0.690	–
Control	6.64 (1.95)	6.53 (1.93)	Condition x sweetener	0.01	1,181	0.931	–
			Time point x condition x sweetener	0.40	1,181	0.526	–

Note: M: Mean, *SD*: Standard deviation (knowledge range 0: low knowledge to 7: high knowledge; other ranges 1: do not agree at all to 9: agree completely).

after the video, $F(1, 183) = 5.24$, $p = .023$, but not the control groups $F(1, 183) = 1.06$, $p = .306$. Thus, the hypothesis that the video would increase the acceptance of the sweeteners is accepted.

4.3. Participants' Evaluations of the Videos

Aside from the experimental effects investigated previously, participants were asked to conduct a subjective evaluation of the videos. Table V presents the means and standard deviations of the evaluated criteria for each group. Two-way ANOVAs were conducted to investigate group differences in the evaluation of the video.[1] The three videos were

[1]Despite the fact that the control groups had seen the same video, the ANOVA was conducted for all four combinations to examine the potential differences in the control groups.

Table V. Evaluation of the Videos and Two-Way ANOVAs

	Understandable *M* (*SD*)	Believable *M* (*SD*)	Interesting *M* (*SD*)	Learnt Something New Through the Video *M* (*SD*)
Aspartame				
Experimental	8.52 (0.98)	7.23 (2.28)	7.82 (1.72)	7.57 (2.07)
Control	8.10 (1.43)	7.26 (1.78)	6.78 (2.04)	6.36 (2.38)
Steviolglycoside				
Experimental	8.05 (1.38)	7.00 (2.20)	7.17 (2.07)	7.67 (2.15)
Control	8.20 (1.35)	7.39 (1.73)	7.45 (1.67)	6.80 (2.49)

Note: M: Mean, *SD*: Standard deviation (range 1: do not agree at all to 9: agree completely).

perceived similarly in terms of being "understandable" and "believable"; neither condition nor sweetener had a significant main effect, nor was there a significant interaction effect ($Fs < 2.27$, $ps > .133$). For the criteria "interesting" solely a significant interaction effect of condition and sweetener was found ($F(1, 181) = 5.66$, $p = .018$, $\eta^2 = .03$). The aspartame control group judged the video to be less "interesting" than the other three groups. For the criteria of whether participants had "learnt something new through the video" there was only a significant main effect of condition ($F(1, 181) = 9.48$, $p = .002$, $\eta^2 = .05$). The control groups judged to have learnt less new information than the experimental groups.

Participants with the aspartame questionnaire ($M = 3.89$, $SD = 2.50$) rated the influence of the video on their attitudes and feelings similar as participants with the steviolglycoside questionnaire ($M = 4.79$, $SD = 2.30$, $t(84) = -1.73$, $p = .087$). The video about steviolglycoside ($M = 3.93$, $SD = 2.27$) was perceived as significantly more influential on the participants' consumer behaviour than the video about aspartame ($M = 2.84$, $SD = 2.41$, $t(84) = -2.15$, $p = .034$, $r = .23$). Through an open question the participants were asked to indicate how the video could be improved further. Most of the suggestions were related to the aesthetic aspects of the video (e.g., more color, more animation; $n = 8$). The other participants wanted more information about the goal of the video (e.g., public information, advertisement for sweetener; $n = 3$) and the source of the information and video (e.g., logo of governmental office or scientific institute; $n = 5$). The participants also wanted more tangible examples ($n = 3$) and a more humorous tone for the video ($n = 1$).

5. DISCUSSION

5.1. More Knowledge, Positive Thoughts and Feelings and Less Risk Perception After the Experimental Video

As found in previous research,[1,6] the participants in this study had little knowledge of the scientific risk assessment and regulation of food additives, such as aspartame or steviolglycoside. However, showing a short motion graph video appears to be a promising approach to communicate complex topics to interested people. The results suggest that the participants understood the information given in the video and retained it, at least in the short term. The response distributions in Fig. 2 show that "do not know" and incorrect responses were lower after watching the video in the experimental groups than in the control groups.

Apart from an increase in knowledge, the results suggest that the video increased positive thoughts and feelings towards both sweeteners and reduced risk perception. However, no effect of the video on benefit perception was found. As people do not judge risks and benefits entirely independently,[16] risk, as well as benefit, perceptions were of interest in this study. However, as no information regarding the benefits of aspartame or steviolglycoside was given in the video, this nonsignificant effect of the video on benefit perception is not all that surprising. Furthermore, results suggest that the video increased consumers' acceptance of the sweeteners under investigation. However, effect sizes for the significant interaction effects for acceptance and risk perception were small ($\eta^2 = .03$; $\eta^2 = .08$) and thus, these findings should not be overinterpreted. The main goal of

the study was not to motivate consumers to accept or use sweeteners but rather to create informed consumers who base their decisions in choosing food on facts. As will be discussed in Section 5.3, the present sample had a rather neutral or positive perception and high acceptance of aspartame and of steviolglycoside. Perhaps the results may be different in a more discerning sample with lower acceptance.

5.2. Different Perceptions Depending on the Sweetener's Origin

As expected, the participants perceived the sweetener of natural origin, steviolglycoside, more positively than the sweetener of artificial origin, aspartame. Consistent with previous literature,[8,9] the participants exhibited a preference for the sweetener of natural origin, which might first and foremost be explained by the "naturalness halo." Generally, people prefer and ascribe positive attributes to foods and entities of natural origin.[9,25,33] Moreover, aspartame has received much negative media attention after the release of the study results of the Ramazzini Institute linking aspartame to cancer in rats.[34,35] However, because of severe deficiencies in the study design, the results were declared faulty by other experts,[36,37] and a complete reevaluation of the safety of aspartame in 2013 came to the conclusion that the consumption of aspartame at the current ADI is safe for human health.[38] Nonetheless, consumers may have believed and remembered the negative headlines, as predicted by the negativity bias.[18,19] Conversely, steviolglycoside received more positive media attention, emphasizing its natural origin and health benefits.[39] Despite the fact that the scientific risk assessment of steviolglycoside is not yet completed and, therefore, the use of steviolglycoside in foods is not generally approved, consumers deem it as safer than the thoroughly investigated aspartame.[40] Altogether, the results related to the two sweeteners confirm previous findings that naturalness is a fundamental criterion to judge foods, potential food risks, or processes.[33]

Additional interesting results of the study were the relationships among the included variables before watching the video, separated by sweetener. Whereas the participants who had trust in the regulators had more positive thoughts and feelings, less risk perceptions, and more acceptance for aspartame, no or significantly smaller relationships were found among these variables for steviolglycoside. This result may be ascribed to the fact that consumers do not see the need to regulate steviolglycoside. Therefore, whether participants trust the regulators of food additives or not has no implications for the perception of steviolglycoside. Furthermore, preference for natural foods was significantly related to the participants' thoughts and feelings, risk perception, acceptance, and naturalness perception of aspartame. Whether people prefer natural foods or not did not matter for steviolglycoside. This finding is surprising, as people who prefer natural foods would be expected to consider steviolglycoside more positively than people, who do not care about naturalness. A potential explanation for this might be that the introductory text placed steviolglycoside in the category of food additives, which have been shown to be antagonistic to naturalness.[8,25,41] Thus, although steviolglycoside was definitely perceived as more natural than aspartame, it was not perceived as a natural entity either. Moreover, the participants could have been unfamiliar with the more recently introduced sweetener steviolglycoside compared with aspartame, and did not have the opportunity to form an opinion about the former yet.

5.3. Strengths and Limitations

To the best of our knowledge, this study was the first to investigate a concrete risk communication in the field of food additives. The questionnaire items were based on qualitative research and were previously pretested in a published quantitative study.[6] The material for the video was obtained from intensive literature research and expert interviews, and it mainly aimed at targeting consumers' misconceptions and knowledge gaps. Thus, the present study was well grounded in the methodology of the MMA[20] and incorporated the views of both food safety experts and lay consumers. However, an important limitation, namely, sampling bias, should be discussed at this point. Generally, the participants had rather neutral or positive attitudes towards sweeteners. Their willingness to take part in this study indicates that they are interested in the topic of sweeteners and perhaps have rather positive opinions about them. Based on the data from this study it is not possible to predict whether and how the video would be received by a sample with highly negative views. A similar mentionable limitation might be that variables were assessed before and after presentation of the videos. This pretest might have sensitized the participants for the topic. The small, but significant, change in risk perception in the control

groups substantiates this limitation and suggests that asking consumers questions about their knowledge about sweeteners and their safety assessment, without providing them with the correct responses right away, might have increased their risk perception. However, the pretest was necessary because we were interested in the changes that the video might induce within the participants, and control and experimental groups were sensitized in the same way. Another critical point is the fact that follow-up knowledge was assessed directly after the presentation of the video. Thus, finding evidence related to long-term retention or long-term effects on the investigated variables was not possible.

5.4. Implications for Future Research

In future studies, the sampling issue mentioned in the previous section should be addressed. Certain consumers may benefit from watching the video, whereas others may not. Consumers who completely reject sweeteners, such as aspartame, are likely to be less willing to consider information about the regulation of sweeteners than consumers who value sweeteners' benefits, but are simply uncertain about their potential health implications. Identifying these different consumer groups would be interesting in order to give recommendations on the target group of this risk communication. Moreover, whether people retain the knowledge in the long term and whether the video triggers an active search for additional information (e.g., from the Internet, in magazines) should be determined. The success of risk communication is related to the trust that people have in the information source.[42–44] Therefore, future studies could investigate whether the outcome differs depending on the indicated information source of the video (e.g., government office, food industry, consumer protection agency, university). To enrich the knowledge on what makes or breaks naturalness,[28,29] different sweeteners with various degrees of implied naturalness could be investigated. Implied naturalness could vary from the purely natural stevia leaves, to the naturally extracted steviolglycoside, to a synthesized version of the steviolglycoside molecule, to aspartame.

6. CONCLUSION

In sum, informing consumers about the scientific risk assessment of food additives, such as sweeteners, and the dose-response relationship through an easily accessible form can successfully transfer knowledge, increase positive thoughts and feelings, and reduce risk perceptions. Most participants liked the videos informing about the safety of aspartame or steviolglycoside, considered them interesting, understandable, believable, and indicated that they had learnt something new. The European Food Safety Authority (EFSA) already uses videos on its website to inform consumers about different food topics, such as establishing safe levels for chemicals in foods.[45] This study provides evidence that this indeed might be a promising approach and that it can be implemented by other offices or agencies interested in informing consumers.

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APPENDIX

The following section presents the English translation of the German text spoken during the experimental motion graph video, and a screenshot from the video (Fig. A1). The text spoken in the control video is not presented because of text limitations. The three German videos and the text of the control video are available upon request from the corresponding author.

Experimental Video (EG1 and EG2)

This video is about the process of approval and control of the artificially manufactured food additive aspartame (of the naturally extracted food additive steviolglycoside). As in all food additives, aspartame (steviolglycoside) has not been directly approved for use in foods, but has been intensively tested for health safety. In regular intervals, the health safety is reevaluated with the latest research methods.

Four factors are especially considered: first, whether the administration of different doses of aspartame (steviolglycoside) leads to short-term or long-term side effects in animals or whether there is evidence of cancerogenic or mutagenic properties; second, whether aspartame (steviolglycoside) is preserved or metabolized in the body, that is, whether aspartame (steviolglycoside) is broken down or changed in the body; third, in what amounts the food is usually consumed; and fourth, which groups of people—children or adults—usually consume the

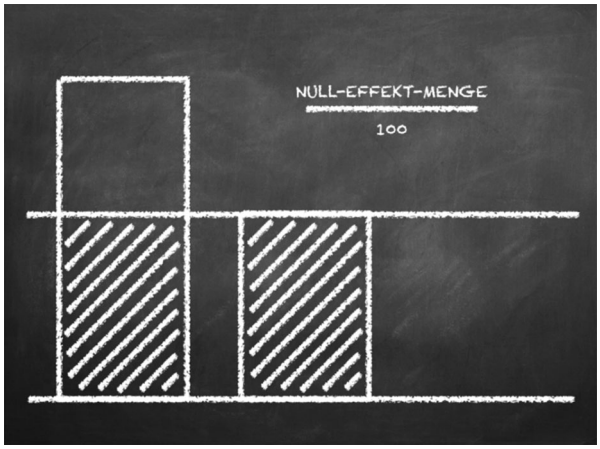

Fig. A1. Screenshot from the experimental videos about aspartame and steviolglycoside, respectively.

food. The toxicological principle "the dose makes the poison" is valid for aspartame (steviolglycoside) same as for other substances. This principle indicates that a substance is not per se harmful or not harmful to health: harmfulness depends on the consumed amount. Therefore, it is regulated by law how much aspartame (steviolglycoside) a certain food may contain. This amount is calculated in three steps:

In the first step, the amount of aspartame (steviolglycoside) that does not cause health effects in study animals is determined. This amount is determined on the basis of all available data from previously conducted studies. This line represents the highest amount of aspartame (steviolglycoside) that was fed daily to study animals throughout their lifetime without causing health effects. Here, this amount is called the no-observed-effect level. This level is subsequently divided by the so-called safety factor of 100. This factor accounts for the fact that most data are based on animal studies and that different people—children and adults, older and younger people—consume aspartame (steviolglycoside). In the graphic, the resulting dose is labeled "acceptable-amount' and describes the amount of aspartame (steviolglycoside) that can be consumed daily over a lifetime without raising health concerns. As this amount indicates lifelong consumption, occasionally exceeding this amount is not harmful. The acceptable-amount depends on the body weight of a person. A person with a body weight of 60 kg would have to drink more than 10 cans of a drink sweetened with aspartame (steviolglycoside) per day over his/her life to reach this acceptable-amount.

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