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ORIGINAL ARTICLE

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Poor understanding of allergen labelling by allergic and non-allergic consumers

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Abstract

Background: Understanding consumers' interpretation of allergy information is crucial for effective food safety policies. We evaluated consumer understanding of allergy information on foods in controlled, experimental studies.

Method: Using 18 packaged foods, we evaluated consumer understanding of information about allergens in two experiments: First, a comparison of foods with no stated allergen versus allergen as a stated ingredient versus a precautionary allergen label (PAL); second, a comparison of three common variants of PAL. In each experiment, consumers with and without self-reported food allergy were asked to estimate the risk of allergic reaction and to rate the comprehensibility of the allergen information. In the second experiment, consumers were also asked which form of PAL they preferred.

Results: Risk of reaction was assessed as high and low for foods with the allergen stated as ingredient, or without any mention of allergen. However, risk assessment for PAL varied and was judged as higher by non-allergic than allergic participants (82% vs. 58%, $p < .001$). Understanding of risk associated with PAL also varied by health literacy ($p < .001$). Both allergic and non-allergic consumers judged all forms of allergy information to be unclear, especially products with no allergy information for non-allergic consumers. Products with a 'Produced in a Factory' PAL were perceived as less risky than 'May contain' or 'Traces of' PALs ($p < .001$), less than 40% of participants judged PAL information to be comprehensible, and participants preferred 'May contain' over the other PALs.

Conclusion: Both allergic and non-allergic consumers find allergen information difficult to interpret on packaged foods and misunderstand PAL, incorrectly distinguishing different risk levels for different PAL wording. Clearer allergy information guidelines are called for, and the use of only one PAL wording is recommended.

1 | INTRODUCTION

Food allergy (FA) frequently occurs. The prevalence of self-reported or probable FA varies between countries, but is estimated to be almost 6% in the Netherlands.[1,2] Food allergy impacts quality of life because of frequent allergic symptoms, dietary interventions to reduce the risk of allergic reactions, anxiety and limitations in social life.[3,4] In an attempt to prevent allergic reactions to food, EU legislation requires labelling of pre-packaged products containing any of 14 allergenic foods.[5] Precautionary allergen labelling (PAL) is a voluntary way of labelling foods by producers to warn consumers for the risk of unintended presence of allergens in products. There are no guidelines for the wording, nor for when to warn.

Despite ingredient declaration legislation and PAL, allergic reactions to food frequently occur. This was shown for Canadian and Australian children[6,7] and confirmed in a literature review[8] of studies among food allergic patients (>12 yrs old). A recent prospective study in adults[9] showed that almost half of all patients experienced unexpected allergic reactions, mostly in the moderate or severe categories. Most reactions (41%) were on pre-packaged food.

Reading labels does not prevent allergic reactions[9] because of misunderstanding of labels and the use of unspecific terms,[10] lack of clarity of PAL[11] and a weak relation between warnings and actual presence of allergens.[12-15] A substantial proportion of allergic consumers even report not to read allergy information or ignore PALs.[12,16] They decide whether or not to use a product based on experience[17] or on other heuristics.[18]

Different wordings of PAL are used on products[19] leading consumers to make unjustified risk assessments. Allergic and non-allergic consumers tend to distinguish different risk levels with different PAL wordings.[20-22] All of these data are based on consumers' self-reports and are often retrospective, whereas a direct test of interpretations of allergy information has never been performed.

It is crucial to understand how consumers interpret allergy information on food labels to improve allergy information. A cognitive model of nutrition label use[23] describes how food label understanding depends on the amount of relevant existing knowledge. This may hinge on whether or not a consumer is experienced in using the information: a food allergic consumer will have gained more knowledge on allergens than a non-allergic consumer. Another related factor is health literacy, 'the ability of individuals to gain access to, understand and use information in ways which promote and maintain good health'.[24-26] In several other studies, the focus has been on preferences for different allergy information options.[27,28]

The aim of this study was (1) to compare the risk assessments of allergy information in a controlled experiment, generalizing across a variety of food products, using fake products to reduce biases due to previous product experiences or brands, (2) to measure the interpretation of allergy information in the ingredients list and PAL, (3) to compare the interpretations of allergy information between allergic and non-allergic consumers and for different levels of health literacy and (4) to connect risk assessments of products to evaluations of comprehensibility and preferences for a certain PAL wording.

Key Messages

- Less than 50% of allergic and non-allergic participants judge allergy information to be clear.
- Allergic consumers attribute lower risks to products with PAL than consumers without food allergy.
- Different risks are attributed to different PALs, especially by consumers with relatively high health literacy.

In this study, a broad range of participants was included varying from consumers with confirmed relatively severe allergies to novice non-allergic participants who were asked to imagine to be grocery shopping for someone with a food allergy. Experienced consumers may have developed idiosyncratic rules of thumb to decide which products they can use safely or which warnings can be safely ignored. This may lead to different risk assessments and comprehensibility judgements compared to those of novices who are confronted with the same labels.

2 | METHOD

2.1 | Design

Two experimental mixed-model studies were carried out. Both experiments were conducted simultaneously and in similar ways, and in each, risk assessment and comprehensibility of allergy information was investigated for three conditions. Every subject rated the risk of consumption by an allergic person of a mixed set of 18 existing products of fictitious brands with allergy information. In the Ingredients Experiment, six products had peanut as an ingredient, six products had a 'May contain peanut'-PAL, and on six products peanut was not mentioned as an ingredient nor mentioned in PAL. In the PAL experiment, the same ratings were elicited for the same 18 products but with three different PAL wordings used most often on Dutch packaged foods ('May contain peanut' vs. 'May contain traces of peanut' vs. 'Produced in a factory which also processes peanut'). S1 (Tables S1.1–S1.3) shows how the materials were varied within and between participants in both experiments. Additionally, in the PAL experiment, we assessed the preference for PAL wordings in a series of three direct comparison tasks.

2.2 | Data sources

Both experiments consisted of an online questionnaire in Dutch, consisting of four parts: (1) demographic questions, (2) knowledge

of food allergies and personal relevance of this knowledge, (3) actual experiment and (4) health literacy test (see S2). The studies were approved at Utrecht University by the Ethical Committee of the Faculty of Arts #Lentz101-02–2018.

The population consisted of adult consumers, either with 'self-reported food allergy or intolerance' (ie 'allergic') or non-allergic consumers, enrolled in the experiment during a period of ten days in May 2018. They were recruited through the membership lists and Facebook pages of two Dutch patient support groups as well as a convenience sample of consumers from the network of participating Master students. Written informed consent was obtained. Inclusion criteria were age 16 years and older and Dutch speaking.

2.3 | Variables

For all types of allergy information on the 18 products, risk assessment and comprehensibility were measured, each with a 5-points scale question. See S3 for examples of the allergen information in each version and the measures used.

The study focussed on two moderating variables: allergy and health literacy. Allergy refers to whether or not a participant has one or more self-reported (either or not physician-confirmed) food allergies. Health literacy was assessed with a slightly adapted test of health literacy (NVS-D.[29] This test is relevant to food allergies as it comprises a food label interpretation test (see S4 and Fig S4.1). In order to assess whether participants with relatively high levels of health literacy in our sample were better capable of correctly interpreting allergy information compared to participants with relatively lower levels of health literacy, we dichotomized the sample in a group above the Median (LitM+) and a group below the Median and including the Median (LitM-) with relatively low health literacy.

2.4 | Statistical analyses

Observations for risk assessment and comprehensibility proved to be rather skewed. Therefore, these dependent variables were dichotomized (S3). Observations were nested both within participants and within products, so we specified a multilevel model in SPSS26 for binomial data,[30,31] in which the (fixed) effects for condition, allergy and health literacy (and their interactions) were estimated, as well as a variance component for the differences between participants and for the differences between products (see S5). In multilevel models for binomial data, typically models and statistical testing are based on logit transformations of the observed data, which constrains the estimated proportions to the allowed parameter space (between 0 and 1).[32] Statistical tests are based on these logits (see S5, Tables S5.1 and S5.2). For graphical presentation of the results and easier interpretation, the logits are transformed back to proportions. We estimated a saturated model, but will report significant effects only and describe general patterns.

3 | RESULTS

3.1 | Participants

A total of 238 people responded to our calls. Participants who did not complete all questions related to the dependent variables or who were younger than 16 (and hence not likely to be the prime decision maker with respect to daily food products) were excluded.

In the Ingredients Experiment, 102 participants were included, 48 non-allergic consumers and 54 allergic consumers (defined as consumers with a self-reported food allergy or intolerance, see Table 1 for the proportion of physician-confirmed allergies). In the Ingredients experiment, 48.5% of the participants belonged to LitM+, whereas 51.5% belonged to LitM-. The mean age was 33.9 years (SD 12.6), range 16–62 years, and 79% was female. In the self-reported allergy group, most allergies were peanut (59.3%) and nuts (57.4%). No differences, except for allergies, were found between allergic and non-allergic participants for gender, age, education or health literacy ($p < .05$).

In the PAL experiment, 99 participants were included, 57 non-allergic consumers and 42 consumers with self-reported food allergy or intolerance. The LitM+ group consisted of 41.3% of participants, whereas 58.7% belonged to the LitM− group. In this experiment, the mean age was 33.7 (SD 13.0) years, range 17–65 years, and 74% was female. Most reported allergies were nuts (47.6%) and peanut (42.9%). No differences were found between allergic and non-allergic participants for gender, age, education or health literacy, except for allergies. Table 1 gives an overview of participant characteristics in both experiments.

3.2 | Results of the ingredients experiment

3.2.1 | Risk assessment

Figure 1 shows the proportion of participants who judged a product to be unsafe to use for someone with an allergy. A distinction is made based on allergy, for example between participants with or without a self-reported food allergy or intolerance (Figure 1A), and on health literacy, for example between participants with relatively high (LitM+) and relatively low (LitM−) levels of health literacy (Figure 1B). The assessed risk depends on the type of allergy information provided (F (2, 1827) = 281.85, $p < .001$). Figure 1A and B both show that products with peanut in the ingredients list are assessed to be most risky to use for someone with an allergy, whereas products without a mention of peanut are considered most safe to use. The attributed risk of products with peanut in PAL is in between those of the other conditions.

Only in the PAL condition, the risks attributed depend of Allergy. Figure 1A shows that non-allergic participants consider a product with PAL riskier to eat for an allergic person than allergic participants (F (2, 1827) = 6.94, $p < .001$). Figure 1B shows that the risks attributed to products with PAL also depend of health literacy: less health literate

TABLE 1 Baseline participants' characteristics in ingredients experiment (Experiment1) and PAL experiment (Experiment 2)

	Ingredients Experiment		PAL experiment	
	No allergy[a]	Allergy or intolerance[a]	No allergy[a]	Allergy or intolerance[a]
	n (%)	n (%)	n (%)	n (%)
Gender				
Male	13 (27.1)	8 (14.8)	19 (33.30)	7 (16.7)
Female	35 (72.9)	46 (85.2)	38 (66.70)	35 (83.3)
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Age (years)	33.9 (12.9)	33.8 (12.5)	34.7 (13.9)	32.3 (11.8)
	n (%)	**n (%)**	**n (%)**	**n (%)**
Educational level[b]				
Low	4 (8.3)	1 (1.9)	3 (5.3)	0
Medium	15 (31.3)	18 (33.3)	24 (42.1)	18 (42.9)
High	29 (60.4)	35 (64.8)	30 (52.6)	24 (57.1)
Native Dutch speaker				
Yes	47 (97.9)	52 (96.3)	57 (100)	42 (100)
No	1 (2.1)	2 (3.7)	0	0
Personal situation				
Student	13 (27.1)	10 (18.5)	11 (19.3)	13 (31.0)
Working	32 (66.7)	40 (74.1)	43 (75.4)	27 (64.3)
Retired	0	0	0	0
Looking for work	0	1 (1.9)	0	1 (2.4)
Chronically ill-not able to work	1 (2.1)	1 (1.9)	1 (1.8)	1 (2.4)
Not working	2 (4.2)	2 (3.7)	2 (3.5)	0
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Duration food allergy/intolerance in years	Not applicable	18.8 (12.5)	Not applicable	15.9 (8.9)
	n (%)	**n (%)**	**n (%)**	**n (%)**
Medical diagnosis of food allergy				
Yes	0	47 (87.0)	0	32 (76.2)
No	0	7 (13.0)	0	10 (23.8)
Allergies				
Peanut	0	32 (59.3)	0	18 (42.9)
Nuts	0	31 (57.4)	0	20 (47.6)
Fruit/vegetables	0	15 (27.8)	0	10 (23.8)
Milk	0	13 (24.1)	0	13 (31.0)
Crustacea	0	9 (16.7)	0	8 (19.0)
Soy	0	6 (11.1)	0	9 (21.4)
Sesam	0	6 (11.1)	0	3 (7.1)
Lupine	0	6 (11.1)	0	3 (7.1)
Gluten	0	5 (9.3)	0	1 (2.4)
Egg	0	5 (9.3)	0	2 (4.8)
Fish	0	4 (7.4)	0	2 (4.8)
Mollusc	0	4 (7.4)	0	3 (7.1)
Celery	0	4 (7.4)	0	1 (2.4)
Sulphur dioxide and sulphite	0	1 (1.9)	0	2 (4.8)
Mustard	0	0	0	1 (2.4)

(Continues)

TABLE 1 (Continued)

	Ingredients Experiment		PAL experiment	
	No allergy[a]	Allergy or intolerance[a]	No allergy[a]	Allergy or intolerance[a]
	n (%)	n (%)	n (%)	n (%)
Other[c]	0	11 (20.4)	0	8 (19.0)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Health literacy _total score	4.7 (1.6)	5.0 (1.6)	4.6 (1.6)	5.0 (1.2)

[a]The distinction between the allergy vs. no allergy group was made with the question (translated from Dutch): Do you have a food intolerance or allergy for certain foods? 0 yes an allergy 0 yes an intolerance 0 no.

[b]Educational level: Low = elementary education, Medium = high school or middle-level applied education, High = higher professional or academic education.

[c]Other allergens include, for example allergy for meat, wheat, seeds or histamine intolerance.

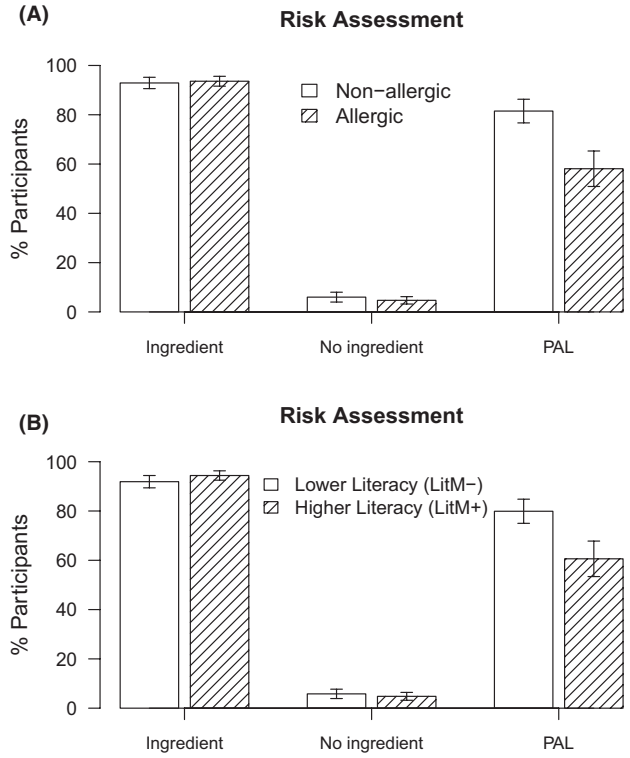

FIGURE 1 (A) The effect of types of allergy information on risk assessment in the ingredients experiment by allergy). Percentage of participants (0–100%) attributing risk of eating a product (mean across 18 food products) for an allergic person after reading food labels with different information about peanut: peanut as an ingredient; peanut not in the ingredients list and not in PAL; and peanut in PAL. Note: I indicates standard errors. (B) The effect of types of allergy information on risk assessment in the ingredients experiment by health literacy. Percentage of participants (0–100%) attributing risk of eating a product (mean across 18 food products) for an allergic person after reading food labels with different information about peanut: peanut as an ingredient; peanut not in the ingredients list and not in PAL; and peanut in PAL. Note: I indicates standard errors

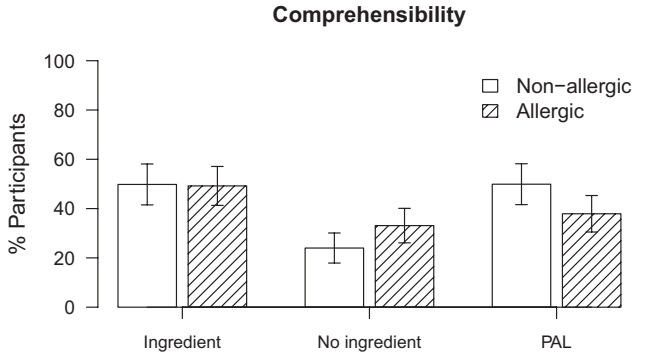

FIGURE 2 The effect of types of allergy information on comprehension assessment in the ingredients experiment by allergy. Percentage of participants (0–100%) judging the allergy information to be comprehensible (mean across 18 food products) after reading food labels with different information about peanut: peanut as an ingredient; peanut as PAL; and peanut not in the ingredients. Note: I indicates standard errors

participants (LitM−) are more likely to expect a higher risk when a PAL is provided compared to LitM+ participants (F (2, 1827) = 7.23, $p < .001$).

Not presented in Figure 1 are the large differences between participants ($S^2_{participants}$ = 1.48, SE = .31) or differences between the 18 food products ($S^2_{products}$ = .73, SE = .29), but they can be derived from the model and data in Table S4. For instance, risk assessment by (95% of) the allergic literate participants of products with peanut as an ingredient ranges from 77% to 99% across products, which means that some participants assess the risk to be much higher than others. Also differences between products were observed: some products with peanuts as an ingredient are only considered risky by 74% of allergic LitM+ participants, whereas other products are considered risky by 94% of the allergic LitM+ participants.

3.2.2 | Comprehensibility

Only about 50% of allergic and non-allergic participants thinks the allergy information is comprehensible. Figure 2 shows comprehensibility judgements differ significantly between the three conditions (F (2, 1827) = 19.77, $p < .001$). However, these differences between conditions depend on allergy (F (2, 1827) = 4.96, p = .007): participants with a self-reported food allergy or intolerance do not think one type of allergy information is more comprehensible than the

other, whereas non-allergic participants perceive products without the allergen mentioned less comprehensible compared to products with the allergen mentioned as an ingredient or in PAL. The variation in comprehensibility judgements between participants is again large, but differences between products failed to reach significance (see S5).

3.3 | Results of the PAL experiment

3.3.1 | Risk assessment

The risk of the 18 products was assessed for three conditions: 'May contain peanut', 'May contain traces of peanut' and 'Produced in a factory which also processes peanut' (Figure 3). Participants judged the risk of products in the three conditions significantly differently (F (2, 1773) = 75.38, $p < .001$). Risks in the factory condition are perceived smaller than in the other conditions.

The risk assessment scores were similar for allergic versus non-allergic participants, but do depend on participants' Health Literacy (F (2, 1773) = 12.48, $p < .001$): for LitM- participants, the differences in risk between products in the May Contain-condition vs. the May Contain Traces-condition are very small, whereas higher health literate participants (LitM+) attribute lower risks to the Traces of PAL, thereby causing a larger difference in risk assessment between the May contain-condition and the Traces-condition.

The differences between participants proved to be extremely large ($S^2_{participants}$ = 11.02, SE = 2.00). For instance, the risk assessment by (95% of) the allergic literate respondents of products that 'May contain peanut' varies from 2% to 99%; some participants hardly see any risk in products with this warning, whereas others consistently attribute high risks to products with this warning. Differences between products did not reach significance (see Table S5).

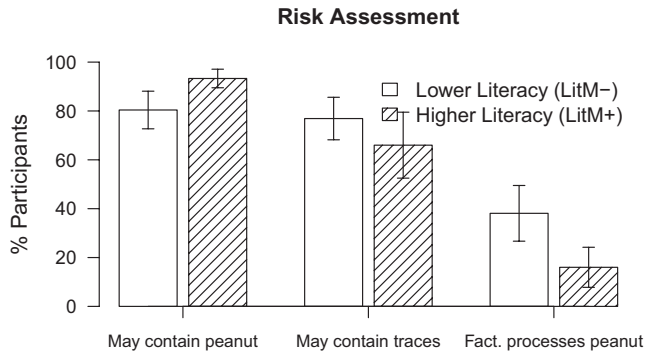

FIGURE 3 The effect of types of PAL information on risk assessment in the PAL experiment by health literacy. Percentage (0–100%) of participants (across 18 food products) attributing risk to eating a product for an allergic person after reading food labels with different PAL wordings about peanut: *May contain peanut—May contain traces of peanut—Produced in a factory which also processes peanut*, distinguishing between participants with relatively low health literacy (LitM-) and relatively high health literacy (LitM+). Note: I indicates standard errors

3.3.2 | Comprehensibility

Figure 4 shows the comprehensibility of each PAL proved to be rather low. Comprehensibility judgements differ significantly between the three conditions (F (2, 1773) = 5.81, p = .003). Remarkably, these differences are larger for non-allergic participants than for allergic participants (F (2, 1773) = 9.34, $p < .001$). Allergic participants do not significantly distinguish different levels of comprehensibility between conditions, whereas non-allergic participants assess the comprehensibility clearly lower in the factory condition than in the other conditions.

Differences between participants in comprehensibility judgements proved to be large ($S^2_{participants}$ = 9.22, SE = 1.66). For instance, the comprehensibility judgements of (95% of) the allergic LitM+ participants of products that 'May contain peanut' vary from 1% to 98%; some participants judge hardly any of the products with this allergy information to be comprehensible, whereas for others the same information is clear. Differences between products were non-significant (see Table S5).

3.3.3 | PAL preferences

A final task in the PAL experiment was a direct comparison of participants' preferences regarding PAL (see S2). This shows a clear preference for May Contain-labelling above the other two PAL wordings (Table 2). The factory label had the lowest preference scores.

4 | DISCUSSION

4.1 | Key results

Consumers attribute different risks to different presentations of allergy information on food labels. The risk of products with the allergen declared as an ingredient was assessed higher compared to products with PAL. Less-literate consumers and non-allergic consumers attribute higher risks to products with PAL than health literate or consumers with self-reported food allergy or intolerance. Only about 50% of allergic and non-allergic participants judged the allergy information to be clear, especially non-allergic consumers perceived a label without allergy information as more difficult. Products with a 'Produced in a Factory'-PAL were perceived to pose a smaller risk than products with 'May contain peanut'-PAL or 'May contain traces of peanut'-PAL. Differences in risk assessment for different allergy information were larger for higher health literacy levels. The highest overall comprehensibility rating was obtained for the 'May contain peanut'-PAL, and in a direct comparison task participants preferred 'May contain peanut' over the two other PALs tested.

This is the first controlled study to show that different PAL wordings lead to different risk assessments, which is congruent with previous research based on self-reports.[12,18-22] With our controlled study

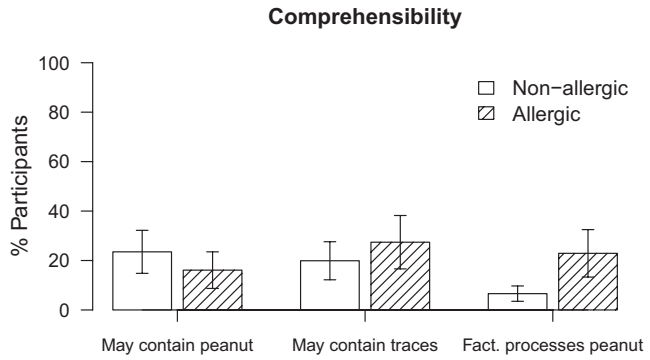

FIGURE 4 The effect of types of PAL information on comprehension assessment in the PAL experiment by allergy. Percentage (0–100%) of participants judging labels as comprehensible after reading 18 food labels with different PAL wordings about peanut: *May contain peanut—May contain traces of peanut—Produced in a factory which also processes peanut*, distinguishing between participants with a (self-reported) food allergy or intolerance versus non-allergic participants. Note: I indicates standard errors

TABLE 2 Proportion of preference for each PAL in three direct comparison tasks (n = 99)

PAL	Preference *n* (%)
May contain peanut	65 (65.7)
May contain traces of peanut	34 (34.3)
May contain traces of peanut	71 (71.7)
Produced in a factory which also processes peanut	28 (28.3)
May contain peanut	73 (73.7)
Produced in a factory which also processes peanut	26 (26.3)

design, we elicited risk assessments and comprehensibility judgements on the spot for a large range of food products, systematically varying allergy information. Thereby, we gained insight in the interpretation of allergy information apart from previous experiences with products and could show how risk assessments vary across different food products. From a communicative point of view,[33,34] it is perfectly rational for consumers to attribute different risk levels to differently worded allergy information. Yet, in fact, the amount of allergen is *not* correlated with PAL wording.[12,15] So the variations in risks attributed to foods due to variations in PAL wordings are actually *incorrect*. Our study shows that many consumers find PAL information difficult to comprehend, with 'May contain'-PAL as least difficult. 'May contain' is also preferred by participants over the other PAL wordings investigated in a direct comparison between PALs.

This is also the first study to directly compare attributed risk levels for products with PAL to products with the allergen in the ingredients list. This comparison shows that products with PAL are assessed to be less risky than products with the allergen as an ingredient. Again, from a communication perspective, this is understandable: a product definitely containing peanut is more risky than a product which might contain peanut. This risk assessment, however, is *incorrect*, as risks are determined not only by probabilities but also amounts of allergens. Products with an allergen listed as ingredient may contain low, negligible or no allergenic protein. In contrast, products with (or without) PAL and without an allergen listed as an ingredient may contain significant levels of allergenic protein and may pose high risks to allergic consumers.[15,28,35]

This study is the first to systematically compare the understanding of allergy information for relevant subgroups. We found that non-allergic participants are more cautious in interpreting allergy information than (self-reported) allergic or food intolerant consumers. And new in this study is that relatively lower health literate (LitM-) consumers seem more cautious than participants with relatively higher levels of health literacy (LitM+). Together this indicates that self-reported food allergic or intolerant (ie experienced) consumers and consumers with a relatively high ability to interpret label information (LitM+) are especially prone to wrongly attribute variations in risk to wording variations in PAL. Allergic consumers may have taken risks with these products before on multiple occasions and may not have experienced reactions. So, they understandably develop a cavalier attitude towards risk. In our view, this finding is a strong indication that the allergy information sends out the wrong cues to those people who really want and need to understand this information.

4.2 | Advice

In communication, it is rational to attribute different risks to information worded differently. Yet, technically, there is no relation between the wording of PAL and the chance on or the level of the allergen. Allergen risks are generally not quantified nor is there any consensus on when and how to communicate different risk levels. Hence, for transparent communication, variation in PAL wording should be avoided. We advise the consistent use of one PAL only. Based on the comparison in this research for the Dutch situation, we advise 'May Contain': the highest risk levels are attributed to products with this PAL, comprehensibility evaluations are relatively positive and it is preferred by participants in a direct comparison task. We also refer to Blom et al.[19] with a standardization proposal for allergy information.

More fundamentally, in our view, the absence of harmonized quantitative guidance regarding PAL poses a risk on consumers. This stresses the importance of a food safety approach based on quantitative allergen risk assessment and risk-based action levels, such as VITAL—instead of hazards (eg [11,36,37]).

4.3 | Limitations

A limitation of any controlled experiment is the ecological validity: in our experiments, plausible but fake products were read and evaluated on a computer screen without any real purchase intentions. Yet, controlled experimentation has many advantages over retrospective behavioural self-reports in terms of causality claims from variation in wording to variation in interpretations, and for generalization across products.

4.4 | Generalizability

We showed risk assessments and comprehensibility judgements that were generic across 18 different food products. This points to generalizability of our findings regarding allergy information understanding across food products in general.

Second, it should be noted that we focussed this study on three PAL wordings most common on Dutch packaged food products. Different PAL wordings are used in different countries. We recommend to restrict to the use of only one PAL worldwide. To choose one, we recommend to investigate and compare the interpretation of a set of common PAL wordings globally.

In this study, we distinguished between consumers with self-reported food allergy or intolerance and non-allergic consumers. It is important to note that we defined 'allergic' by including participants in the allergy group with self-reported medically asserted allergies for peanut and other food allergens, as well as non-asserted allergies. Our study shows that a high level of health literacy does not prevent consumers from interpreting allergy information in PALs in incorrect ways. With that, this study highlights that it is not just certain groups of consumers that need to be trained in using allergy information in a proper way, but it is the allergy information that should be improved. Clear allergy information guidelines are called for, and the use of only one PAL (in the Netherlands: 'May contain') is recommended.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

BH, HO, AK and LL were responsible for acquisition of the funding for this research. BH, AM, GH, AK, MB and LL contributed to the conceptualization and design of this study. BH, LL, LD and AM contributed to the investigation. Formal analysis was conducted by HB, BH and HO. HB and BH provided the data interpretation and drafted the article. HO, MB, KV, YL, GH, AK and LL contributed in a critical interpretation and revision of the article. All authors have read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study were made publicly available in DANS (Data Archiving and Networked Services, https://dans.knaw.nl/nl) upon publication of this study and can be accessed through https://doi.org/10.17026/dans-xj6-tccz

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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