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ORIGINAL ARTICLE

Childhood poisonings: Effects of ambiguous product characteristics on preschool children's categorization of household chemicals

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Abstract

This study investigated preschool children's categorization and risk perception of products with ambiguous product characteristics (e.g., food-like packaging). These characteristics make it difficult for preschool children to categorize household chemicals correctly. This, therefore, increases the risk of unintentional poisoning. We hypothesized that ambiguity arises from different product characteristics, such as the type of packaging, the products' scent, or the packaging's color and transparency. In four behavioral tasks, $N = 108$ preschool children ($M = 43$ months, $SD = 3$) categorized different products and household chemicals with various types of packaging, colors, and scents. Individually wrapped dishwasher tablets were more likely to be categorized as edible than unwrapped ones. Furthermore, children who had interacted with any type of dishwasher tablet in the last 6 months performed better in identifying dishwasher tablets, regardless of packaging type. Household chemicals with a fruity scent were more likely to be categorized as drinkable than those with a chlorine scent. Finally, the children considered black bottles more dangerous and preferred them less than bottles of a different color. In contrast, bottle transparency generally did not seem to affect risk perception and preference. These findings confirm that ambiguous product characteristics influence children's categorization of unknown products and, thus, their risk perception and decision-making. Manufacturers and caregivers are advised to reduce the ambiguity of household chemicals by designing more neutral product packaging and choosing products with more neutral elements, respectively.

KEYWORDS
categorization, household chemicals, preschool children, unintentional poisoning

1 | INTRODUCTION

Children accounted for 17,776 out of 32,928 poisoning incidents in Switzerland in 2021, and approximately one third of these incidents can be attributed to household chemicals (Tox Info Suisse, 2022). Although most of these poisoning cases did not result in severe consequences, they are nevertheless a burden on the health-care system and thus a public health issue in Switzerland and worldwide (Kamboj et al., 2020; Rosenman et al., 2021; Weiler & Kupferschmidt, 2020). Epidemiological data show that most poisoning incidents in children occur before age five and include many forms of exposure (e.g., ingestion, skin, or eye contact; McKenzie et al., 2010; Weiler & Kupferschmidt, 2020). During this time, children's mobility and cognitive abilities develop rapidly, allowing them to access previously inaccessible areas and process more information when categorizing objects (e.g., packaging, labels, and base-rate

information; Gelman & Meyer, 2011; Gualtieri & Denison, 2018; Owen & Barnes, 2021). Furthermore, caregivers do not always adjust their safety measures to their child's level of mobility, resulting in children's unsupervised exposure to household chemicals (Bearth et al., 2022; Gibbs et al., 2005; Pollack-Nelson & Drago, 2002). Consequently, these unsupervised encounters might lead to children falsely categorizing ambiguous products as safe (e.g., household chemicals with food-like packaging), which could reduce their risk perception. Preliminary research has suggested that product characteristics, such as product labels, materials, colors, scents, or shapes, influence children's categorization processes, preferences, and interactions with household chemicals (Schneider, 1977; Schwebel et al., 2015). The packaging of household chemicals has changed considerably in recent years (e.g., adopting a food-like smell). Therefore, more research is needed on the potentially misleading effect of product characteristics (i.e., type of packaging, scent, color, and transparency) on children's categorization processes and perception of household chemicals.

2 | THEORETICAL BACKGROUND

2.1 | Development of children's categorization abilities

A possible way through which product characteristics influence children's risk perceptions could be through their categorization processes. Children's ability to form categorical representations is central to their perception of the environment (Gelman & Meyer, 2011; Sloutsky & Fisher, 2011). Categorization helps to group information, thus increasing processing efficiency when learning, identifying, and retrieving information. Consequently, categorization reduces cognitive load and helps to effectively manage finite cognitive resources (Gelman & Meyer, 2011; Martin et al., 2002; Owen & Barnes, 2021). Children begin categorizing based on perceptual information long before speaking (Gelman & Meyer, 2011; Mandler & McDonough, 1993; Spencer et al., 1997). With the increase in age, improved language skills, and help from adults and peers, the categories children perceive become more sophisticated, as they can incorporate more information into their categorization processes (Colunga & Smith, 2005; Rakison & Lupyan, 2008). At preschool age, children are already forming categories based on characteristics such as shape, color, and texture (Gelman & Meyer, 2011; Sloutsky & Fisher, 2011).

2.2 | Product characteristics as the final preventive barrier

To prevent unintentional poisoning from household chemicals, it is essential to understand how children categorize objects and to identify the factors that lead children to make incorrect categorizations and, consequently, harmful decisions. In their review, Schwebel et al. (2017) identified four causal factors (i.e., person, location, community and society, and product) that need to be addressed to prevent unintentional poisoning incidents. However, personal and social factors influencing children's risk perception and behavior (e.g., the child's temperament and the social environment; Berry & Schwebel, 2009; Morrongiello & Sedore, 2005) are difficult to change without considerable effort. Furthermore, research has shown that preventive measures that affect location, such as safeguarding the home, are often not adapted to children's mobility (Bryant et al., 2022; Gibbs et al., 2005). Therefore, the product and its effect on children's risk perception can be considered the final barrier between a child and a poisoning incident.

In adults, product characteristics, such as environment-friendly labels, have been found to reduce consumers' risk perceptions (Bearth et al., 2017; Bearth & Siegrist, 2019; Siegrist & Árvai, 2020). Furthermore, products with food-like characteristics, such as labels featuring fruits or bottles shaped like drinking bottles, result in a similar brain response to real food (Basso et al., 2014, 2016). However, limited evidence exists regarding children's risk perceptions of household chemicals (e.g., Schneider, 1977; Schwebel et al., 2015). A preliminary study by Schneider (1977) showed that children were more attracted to square or white containers and containers with small but also large written warnings. However, they were slightly deterred by a skull warning label. Given these results, Schneider (1977) concluded that the attractiveness of a package is the sum of the different attributes constituting packaging. A more recent study by Schwebel et al. (2015) suggested a similar conclusion. Children were more likely to identify square, metallic, and opaque containers, as well as containers with an insect on the label, as dangerous compared to containers with other shapes and materials (Schwebel et al., 2015).

Children's risk perception is also influenced by the similarity of different product characteristics (e.g., labels on hazardous products resembling those on food or toys). For example, children had difficulty categorizing unknown containers with transparent packaging and juice-like liquids as dangerous (Schwebel et al., 2015). Furthermore, children were more likely to categorize household chemicals with labels featuring cartoon characters or animals as child safe compared to regular packaging (Bosshart et al., 2022).

2.3 | Study aims and objectives

In this study, we asked whether the ambiguity of the product characteristics of household chemicals leads preschool-aged children to make incorrect categorizations and therefore hinders their risk perception. We addressed this research question using four tasks, each with its own hypothesis.

In a *Tablet Categorization* Task, we focused on the ambiguous product characteristics of dishwasher tablets. In a past study focusing on the storage of various household chemicals and their influence on children's perceptions, children

had particular difficulty recognizing individually wrapped dishwasher tablets (e.g., each tablet wrapped in white non-dissolvable plastic; Bosshart et al., 2022). We assumed that this difficulty was based on the individual wrapping of dishwasher tablets and the common characteristics of candies. However, this assumption could not be confirmed in the prior study due to methodological constraints in the experimental design. Expanding on this assumption, we investigated the following hypothesis:

H1. Children categorize individually wrapped dishwasher tablets as edible more often than unwrapped tablets.

Transferring household chemicals into secondary containers is still fairly common in Europe and other regions (e.g., Abdelgalil, 2016; Basso et al., 2014; Smolinske & Kaufman, 2007). With secondary containers, children lack important cues to categorize them. Therefore, children must rely on other cues, such as smell, to categorize unknown liquids. In a *Scent Categorization* Task, we, therefore, investigated the effect of ambiguous scents on preschool children's categorization abilities. Children use scent to categorize objects as edible or inedible (Valentin & Chanquoy, 2012) and prefer sweet over sour flavors and scents (Hoffman et al., 2016). Therefore, we expected household chemicals with a fruity scent to lead to false categorizations more often than those with a chlorine scent. However, we did not expect that scent preferences (i.e., sweet over sour) would lead to differences in children's categorization within the category of household chemicals with fruity scents. Consequently, we tested the following hypothesis:

H2. Children are more likely to categorize liquids with either a sweet or a sour, fruity scent as drinkable than liquids with a chlorine scent.

Finally, in the *Dangerous Bottle* and *Bottle-Preference* Tasks, we focused on the colors and transparency of household chemical packaging and their effects on preschool children's perceptions. Children are somewhat inconsistent in their color preferences and perceptions (e.g., Marshall et al., 2006; Walsh et al., 1990), and aside from studies by Schneider (1977) and Schwebel et al. (2015), no other research has investigated the color and transparency of packaging in terms of risk perception and preferences. Nevertheless, a European Commission regulation (No. 276/2010) states that lamp oils and lighter fluids should be packaged only in black and nontransparent packaging. Based on this regulation and the findings discussed above, we expected children to perceive black bottles (nontransparent black packaging or transparent bottles containing a black substance) as more dangerous compared to bottles of other colors. In addition, we expected children to generally perceive nontransparent bottles as more dangerous than transparent bottles, regardless of the bottles' or its contents' color. Therefore, we formulated the following hypotheses:

H3. Children are more likely to categorize black bottles as dangerous than bottles of other colors.

H4. Children categorize nontransparent bottles as dangerous more often than transparent bottles.

3 | METHODS

3.1 | Sample

During 3 months, from September to November 2022, we recruited $N = 120$ Swiss families with preschool-aged children from the German-speaking part of Switzerland. We collected data from one child and one caregiver each. After excluding 12 children who did not meet our inclusion criteria (i.e., cooperation with the researcher and little support from the caregiver), we ended up with a total sample of $N = 108$ children, 55 female (51%) and 53 male (49%).[1] The children's mean age was $M = 43$ months ($SD = 3$) and ranged from 37 to 48 months. Ninety-seven caregivers accompanying the child were female (90%), and 11 were male (10%). The caregivers had a mean age of $M = 38$ years ($SD = 4$) and ranged from 27 to 49 years. Of all caregivers, 65 stated that they had completed higher education (i.e., university degree; 60%), 23 completed higher technical school (21%), 4 held a high school diploma (3%), 15 had completed their vocational training (14%), and 1 stated that they had completed compulsory school (1%). All participants were recruited through the database compiled by the Developmental Psychology: Infancy and Childhood research unit at the University of Zurich. The study protocol and procedure were approved by the ETH Zurich Ethics Commission (Ref: 2022-N-123).

3.2 | Study design and procedure

During the laboratory study, the children completed four behavioral tasks in the order listed below. The entire study was video recorded, with the caregivers giving written consent and the children giving verbal consent prior to recording.

For the Tablet Categorization Task, the child was asked to categorize nine products, specifically five food items and four household cleaning products and supplies available in Swiss retailers (Figure 1, top), as edible or inedible. This task was carried out in a between-subject design, with only the packaging of the 3D-printed fake dishwasher tablets varying between conditions (Figure 1, bottom). The 3D-printed fake dishwasher tablet was either individually wrapped or unwrapped, depending on the condition to which the child was randomly assigned. All products were randomly arranged for each child and presented in three rows opposite two boxes. One box featured a picture of different foods, and the other featured a picture of different cleaning supplies. First, the researcher introduced the child to the task by stating

[1] Sample size may vary between analyses due to children not completing all tasks.

FIGURE 1 Products used in the Tablet Categorization Task, including the two differently wrapped 3D-printed dishwasher tablets.

Note: Depending on the condition, children got either unwrapped (bottom left) or individually wrapped (bottom right) 3D-printed dishwasher tablets. Edible and drinkable food items are denoted by superscripted "a."

FIGURE 2 Products used in the Scent Categorization (top left), Dangerous Bottle (top right), and Bottle-Preference (bottom) tasks.

that he had forgotten to clean up the room and that the child should put these nine products into the corresponding boxes. Then, the researcher recorded in which box the child placed each product.

In the Scent Categorization Task, the researcher presented the child with a closed box containing three flasks (modified saltshakers) with different liquids (chlorine all-purpose cleaner, citrus toilet cleaner, and berry dishwashing liquid), as shown in Figure 2, top left. This task was performed in two steps: In the first step, children had to rate the liquids presented within neutral flasks. The aim was to investigate the effect of scents on children's categorization when confronted with household chemicals transferred into secondary containers. In the second step, children had to rate the liquids within their original packaging. The aim was to investigate the effects of the original packaging on children's scent-based categorization. In the first step, the researcher randomly took a flask from the box. Then, the researcher and the child smelled the liquid and discussed whether the researcher would be safe to drink the liquid inside. This procedure was repeated until the child had seen and smelled all three flasks. Next, the researcher showed the child the product bottles from which the different liquids came and placed them right next to the flasks. The researcher explained that the liquid within the flasks was from the corresponding product bottles and asked again if it would be safe to drink it. For this task, we recorded verbal (e.g., "yes" and "no") and nonverbal (e.g., nodding or shaking of the head) answers to each question before and after showing the corresponding product bottles.

In the Dangerous Bottle Task, the researcher arranged three pairs of liquid dishwashing detergents with transparent and nontransparent packaging, each pair being of a different color (i.e., black, white, and yellow), and placed them in front of the child. Transparently packaged liquid dishwashing detergents contained colored liquids that matched the color of their nontransparent counterpart (Figure 2, top right). The researcher explained to the child that he was looking for the most dangerous of the six bottles and needed help identifying them. He then asked the child to point to the bottle that looked the most dangerous. After the child pointed to a bottle, the researcher thanked the child, took the bottle, and put it in a box. After that, the researcher mentioned that he wondered which was now the most dangerous bottle among the rest and asked the child to point again to the bottle that looked the most dangerous. This procedure was repeated three times.

The Bottle-Preference Task consisted of six pairs of liquid dishwashing detergents with transparent and nontransparent packaging, adding the colors orange, blue, and green to the bottles from the dangerous bottle task (Figure 2, bottom). All products were randomly sorted into three rows and placed in front of the child. The researcher instructed the child to inspect all products carefully and place all products they liked into one box to their right and all the products they disliked into another box to their left. The researcher recorded in which box each product was placed.

After completing all tasks, the child received a small gift valued at approximately $5 and a certificate of participation as compensation. Additionally, the caregivers received a children's book (Pauli, 2018) on the dangers of household chemicals, their warning symbols, and other toxic substances (i.e., plants).

3.3 | Questionnaire

While the child was completing the tasks, the caregiver was asked to complete a short questionnaire assessing demographic variables and caregivers' practices regarding household chemicals. In particular, we assessed the frequency with which children interacted with dishwashing detergents in different types of packaging. We presented pictures of different types of dishwashing detergents to caregivers, including dishwasher tablets with different packaging (i.e., individually wrapped and unwrapped dishwasher tablets). Caregivers indicated for each type of dishwashing detergent whether they had kept the specific product or a similar one at home during the previous 6 months. Caregivers then rated their children's interaction frequency with each product they had at home by answering the question, "In the past six months, how often did your child interact (play or help with the dishes) with the presented product?" on a six-point Likert scale from 1 = "*Never, the product is kept away from the child*" to 6 = "*Daily*." Pictures of all the products shown can be found in the supplementary materials.

3.4 | Data analysis

Data analysis was conducted using R version 4.2.2 (R Core Team, 2022). To analyze whether the packaging of dishwashing tablets (independent variable [IV]) influenced children's identification of these products as edible or inedible (dependent variable [DV]), we conducted a Pearson's chi-squared test. Additionally, we performed a logistic regression analysis of the children's categorization of dishwasher tablets as the DV to control for additional factors (i.e., age, gender, and interaction frequency). For this purpose, interaction frequency was transformed into a bicategorical variable indicating whether the children had interacted with dishwashing tablets in the last 6 months. Furthermore, we used generalized estimated equations (GEE) to analyze children's identification of dangerous products (DV) based on their scents and packaging (IV), again controlling for age and gender. We conducted exact binomial tests and Pearson's chi-squared tests to analyze the effect of packaging color and transparency (IV) on children's product liking and risk perception (DV). Finally, we used GEE to model children's perceptions while controlling for the known confounders age and gender.

4 | RESULTS

4.1 | Dishwasher tablet packaging and its effects on categorization in children

The Tablet Categorization Task was used to investigate the effects of dishwasher tablets' packaging on children's categorization. Figure 3 depicts the percentage of children categorizing dishwasher tablets as edible or inedible for each packaging type. The individually wrapped dishwasher tablets

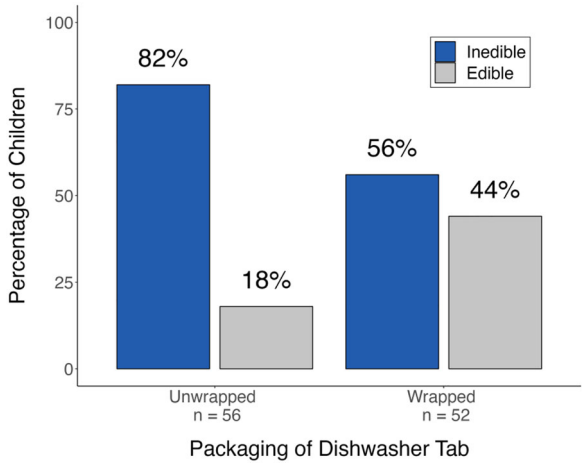

FIGURE 3 Percentage of children who categorized dishwasher tablets as edible or inedible, grouped by type of packaging.

Note: Every child was only assigned one of the two packaging types for dishwasher tablets.

were categorized as edible by 23 children (44%). In comparison, the unwrapped dishwasher tablets were categorized as edible by less than half of the children ($n = 10$, 18%). Furthermore, a Pearson's chi-squared test confirmed a significant difference in the categorization frequency between unwrapped and individually wrapped dishwasher tablets with a small to medium effect size, χ^2 (1, $N = 108$) = 8.84, $p = 0.003$, $\phi = 0.286$. Regarding children's interactions, 60 caregivers (56%) reported that their children had interacted with dishwasher tablets at least once in the last 6 months. Table 1 summarizes the logistic regression modeling of the children's categorization of dishwasher tablets as edible, including the odds ratio (OR). The OR suggests that individually wrapped dishwasher tablets were 4.6 times more likely to be categorized as edible than unwrapped dishwasher tablets. Furthermore, children who did not interact with dishwasher tablets in the last 6 months at least once were 3.5 times more likely to categorize dishwasher tablets as edible than children who did interact with these products during the same period. Finally, the packaging type of the dishwasher tablets that the caregivers had at home did not significantly affect the children's ability to identify them.

4.2 | The effect of scent on children's categorization of household chemicals

Following the Scent Categorization Task, we visualized that the percentage of children who thought the fluid presented was safe to drink before and after showing the corresponding product bottles in Figure 4. Only 105 children completed this task because three did not want to smell the liquids. Before the children saw the product bottles, 25 children (24%) categorized the chlorine all-purpose cleaner liquid as safe to drink, compared to 30 children (29%) and 34 children (32%), who categorized the citrus toilet cleaner liquid and the berry

TABLE 1 Logistic regression of preschoolers' categorization of dishwasher tablets as edible, controlling for gender, age, condition, interaction frequency, and product at home.

Predictors	*B*	*SE B*	Wald χ^2	*p*	*OR*	95% *CI OR*	
						LL	*UL*
Intercept	−0.84	3.69	−0.23	0.819	0.43	0.00	592.96
Gender: Female (Ref.)							
Gender: Male	−0.51	0.49	−1.04	0.299	0.60	0.23	1.58
Age (child)	−0.03	0.09	−0.38	0.701	0.97	0.81	1.15
Condition: Unwrapped (Ref.)							
Condition: Wrapped	1.52	0.49	3.08	0.002**	4.57	1.74	11.99
Interacted with Tabs: Yes (Ref.)							
Interacted with Tabs: No	1.25	0.59	2.10	0.036*	3.47	1.08	11.13
Tablets at home: None (Ref.)							
Tablets at home: Wrapped	−1.28	1.23	−1.04	0.298	0.28	0.03	3.09
Tablets at home: Unwrapped	1.03	0.72	1.43	0.154	2.79	0.68	11.41
Tablets at home: Both	−0.30	0.73	−0.41	0.681	0.74	0.18	3.11

Notes: Interaction frequency was transformed into a bicategorical variable indicating whether children interacted with dishwashing tablets in the last 6 months. $N = 108$, model fit: $\chi^2(7) = 24.5$, $p < 0.001$, McFadden pseudo-$R^2 = 0.18$.
Abbreviations: *CI*, confidence interval; *LL*, lower limit; *OR*, odds ratio; *UL*, upper limit.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

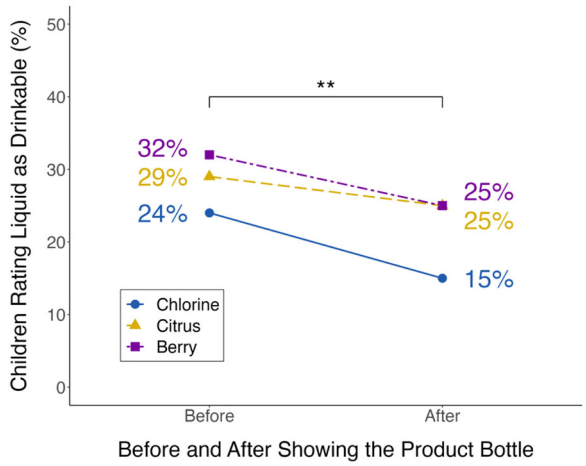

FIGURE 4 Percentage of children who categorized the presented liquid as drinkable based on scent before and after being shown the product bottle.

Note: Products used were a *chlorine* all-purpose cleaner, a *citrus* toilet cleaner, and a *berry* liquid dishwashing detergent. The sample was reduced to $N = 105$ because three children did not complete the task. **$p < 0.01$.

dishwashing liquid as safe to drink, respectively. Table 2 summarizes the results of the GEE modeling of the probability of rating a given liquid as safe to drink while controlling for the packaging of the three household chemicals. Children were 1.5 times more likely to categorize the citrus toilet cleaner and 1.8 times more likely to categorize the berry dishwashing liquid as safe to drink than the chlorine all-purpose cleaner. Additionally, Figure 4 shows that more children categorized the liquid as safe to drink before they saw the product bottle, with the citrus cleaner recording the smallest reduction in wrong answers (4%) compared to the berry dishwashing liquid (7%) and the chlorine cleaner (9%). Overall, children were 1.5 times more likely to categorize any liquid as safe to drink before they saw the product bottle than after they saw the bottle (Table 2).

4.3 | The influence of color and transparency on children's risk perceptions

First, we evaluated only the first decision each child made in the dangerous bottle task to analyze the product characteristics of the "most dangerous" archetype. A total of 49 children (46%) categorized the black bottles as dangerous first, whereas 28 and 31 children categorized the white (26%) and yellow (29%) bottles as dangerous, respectively (see Figure 5). An exact binomial test confirmed that the observed probability ($P_O = 0.46$) of rating a black product as dangerous was significantly higher than the expected probability ($P_E = 0.33$, $N = 108$, $p = 0.01$, 95% CI [0.36, 0.55]). However, the categorizations of both the white ($P_O = 0.26$, $N = 108$, $p = 0.125$, 95% CI [0.18, 0.35]) and yellow ($P_O = 0.29$, $N = 108$, $p = 0.358$, 95% CI [0.20, 0.38]) products did not significantly differ from the expected probability ($P_E = 0.33$). Regarding transparency, about half of the children categorized nontransparent bottles as dangerous, whereas the other half categorized transparent bottles as dangerous (Figure 5). However, a Pearson's chi-squared test confirmed a relationship between color and transparency in children's first decisions, $\chi^2(2, N = 108) = 8.97$, $p = 0.011$, $\phi = 0.288$. Children perceived black nontransparent bottles

TABLE 2 Generalized estimated equation (GEE) for preschoolers' rating of liquids as safe to drink, controlling for age, gender, decision time (before and after being shown bottle) and product type (chlorine, citrus, and berry).

Predictors	*B*	*SE B*	Wald χ^2	*p*	*OR*	95% CI OR	
						LL	*UL*
Intercept	−0.94	2.83	0.11	0.740	0.39	0.00	99.44
Gender: Female (Ref.)							
Gender: Male	−0.68	0.36	3.63	0.057	0.51	0.25	1.02
Age (child)	−0.01	0.06	0.01	0.904	0.99	0.87	1.13
Time: After (Ref.)							
Time: Before	0.37	0.13	7.65	0.006**	1.45	1.11	1.89
Product: Chlorine (Ref.)							
Product: Citrus	0.40	0.16	6.13	0.013*	1.49	1.09	2.04
Product Berry	0.58	0.16	13.78	<0.001***	1.79	1.32	2.43

Notes: $N = 105$, model fit: χ^2 (5) = 33.4, $p < 0.001$.
Abbreviations: *CI*, confidence interval; *LL*, lower limit; *OR*, odds ratio; *UL*, upper limit.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

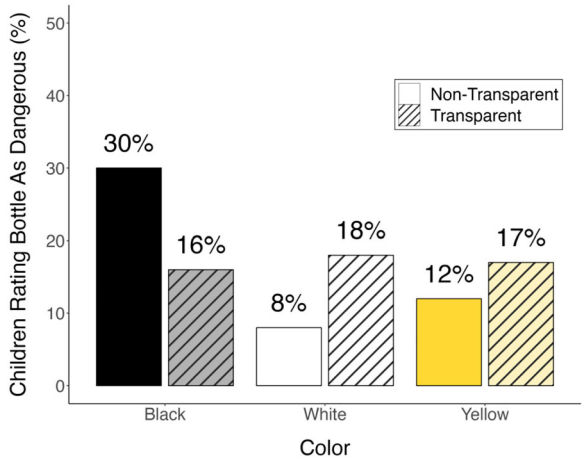

FIGURE 5 Percentage of children who rated bottles as dangerous grouped by color and transparency of the packaging.

Note: Only the first bottle categorized by each child is displayed ($N = 108$).

more often as dangerous than bottles with other combinations of these two attributes.

Second, we analyzed all decisions made by the children to get a more general view of their risk perception regarding color and transparency. Table 3 summarizes the results of the GEE modeling of the children's perceptions of danger regarding color and transparency. Across all bottles categorized, children were roughly 0.5 times less likely to categorize a white or yellow bottle as dangerous compared to a black bottle. In other words, black bottles were approximately two times more likely to be categorized as dangerous than white or yellow bottles.[2] Furthermore, these results show that transparency did not significantly influence children's ratings when all decisions were considered. Additional analyses revealed no overall interaction between color and transparency. The model that included the interactions between color and transparency did not result in an improved model fit; therefore, these interactions were excluded from the final model.

[2] These reciprocal values were calculated using the ratio between the reference and the OR ($\frac{1}{OR}$).

4.4 | The influence of color and transparency on children's preferences

Finally, Table 4 summarizes the results of the bottle-preference task using GEE modeling to determine whether black bottles were significantly less likely to be liked and whether transparency plays a role in children's preferences. In this task, the children liked all the other colors significantly more than the black ones. The odds of a child liking differently colored bottles more than black bottles ranged from 1.53 times for white bottles to 3.61 times for orange bottles. Lastly, the GEE model showed that for overall decisions, transparency generally did not affect children's preferences for bottles.

5 | DISCUSSION

As children get older and explore their environments more independently, they become increasingly likely to encounter unfamiliar items, and they need to decide whether these items are safe. Therefore, household chemicals should not have ambiguous characteristics (e.g., food labels) that make it difficult for younger children to categorize them. This study showed that ambiguity can arise from multiple product characteristics. Children had more difficulty categorizing dishwasher tablets that were individually wrapped in plastic as inedible than unwrapped ones. The perceived similarity

TABLE 3 Generalized estimated equation (GEE) for preschoolers' rating of bottles as dangerous, controlling for gender, age, color, and transparency.

						95% *CI OR*	
Predictors	***B***	***SE B***	**Wald χ^2**	***p***	***OR***	***LL***	***UL***
Intercept	0.71	0.26	7.20	0.007**	2.03	1.21	3.40
Gender: Female (Ref.)							
Gender: Male	−0.01	0.02	0.53	0.468	0.99	0.95	1.02
Age (child)	−0.01	0.00	2.04	0.153	0.99	0.99	1.00
Black (Ref.)							
White	−0.79	0.24	10.87	<0.001***	0.45	0.28	0.73
Yellow	−0.64	0.25	6.28	0.012*	0.53	0.32	0.87
Nontransparent (Ref.)							
Transparent	−0.05	0.17	0.09	0.763	0.95	0.69	1.32

Notes: $N = 108$, model fit: χ^2 (5) = 14.2, $p = 0.014$.
Abbreviations: *CI*, confidence interval; *LL*, lower limit; *OR*, odds ratio; *UL*, upper limit.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

TABLE 4 Generalized estimated equation (GEE) for children's liking of bottles with different colors and transparency, controlling for gender and age.

						95% *CI OR*	
Predictors	***B***	***SE B***	**Wald χ^2**	***p***	***OR***	***LL***	***UL***
Intercept	0.52	1.55	0.11	0.739	1.68	0.08	34.97
Gender: Female (Ref.)							
Gender: Male	0.43	0.23	3.53	0.060	1.54	0.98	2.41
Age (child)	−0.01	0.04	0.09	0.770	0.99	0.92	1.06
Black (Ref.)							
White	0.43	0.21	4.16	0.041*	1.53	1.02	2.30
Blue	0.95	0.24	15.67	<0.001***	2.60	1.62	4.17
Orange	1.28	0.26	23.70	<0.001***	3.61	2.15	6.06
Yellow	1.10	0.26	17.56	<0.001***	3.02	1.80	5.06
Green	0.962	0.2381	16.33	<0.001***	2.62	1.64	4.17
Nontransparent (Ref.)							
Transparent	−0.0558	0.1087	0.26	0.608	0.95	0.76	1.17

Notes: $N = 108$, model fit: χ^2 (8) = 35.6, $p < 0.001$.
Abbreviations: *CI*, confidence interval; *LL*, lower limit; *OR*, odds ratio; *UL*, upper limit.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

of these individually wrapped dishwasher tablets to food (i.e., candy) might explain why children make these false categorizations. This conclusion is consistent with previous findings showing that food-like product characteristics were frequently mentioned when people described their or their children's poisoning (Basso et al., 2014; McKenzie et al., 2010). Another finding from our study is that children who interacted at least once with dishwashing tablets during the last 6 months could better identify them as inedible compared to children who did not interact with these dishwashing tablets. Previous encounters with dishwasher tablets might have helped these children refine their categorizations of safe and unsafe objects that look like candy. As these interactions were reported by their caregivers, we can assume that caregivers were present and could have provided their children with additional information (e.g., "Not everything that looks like candy is candy!"). According to the literature on the development of categorization (e.g., Gelman & Meyer, 2011; Sloutsky & Fisher, 2011), this additional information could have further improved children's categorization, leading to their better performance in the study. An alternative explanation could be that the children's prior experiences with dishwasher tablets helped enhance their understanding of safety issues (e.g., "I understand that not everything that

looks like candy is candy."), which is assumed to be an important factor in reducing preschool children's risk during interactions with hazardous materials (Morrongiello et al., 2014).

Regarding scent, the results of our study suggest that children can be misled by fruity scents and therefore misclassify these types of household chemicals as drinkable. These results align with the reported characteristics of products involved in poisoning incidents with household chemicals. For example, they are often reported as smelling "fruity" (e.g., Basso et al., 2014; Miller et al., 2006). Therefore, we assumed that the fruity smell of the citrus and berry cleaners led to increased ambiguity and children's false categorizations. However, our results also suggest that the packaging of household chemicals can reduce this ambiguity, as children gave fewer wrong answers after they saw the corresponding packaging. Furthermore, we found some differences in the packaging of these household chemicals in reducing the number of incorrect answers the children gave. Compared to the other two products, the packaging of the citrus cleaner resulted in a lower reduction in incorrect responses. A closer look at this citrus cleaner revealed that it has several characteristics that have been identified as misleading by previous studies (e.g., images of animals and food or pointy spout; Bosshart et al., 2022; Schneider, 1977; Schwebel et al., 2015). Finally, our findings regarding color and transparency suggest that preschool children perceive black products as more dangerous and liked them less often. Although transparency influenced children's perceptions of danger in their very first decisions, it generally did not appear to play a role in their perception across all decisions. Therefore, this result provides a more nuanced view of the effects of color and transparency than prior research (Schneider, 1977; Schwebel et al., 2015). Consequently, preschool children who are exposed to different unfamiliar products unsupervised are most likely not to interact first with a black and nontransparent product but rather with something else.

To summarize, our study indicated that caregivers could prevent unintentional poisoning in their children by reducing the ambiguity of household chemicals, by avoiding food-like packaging, light colors, and fruity scents. This additional layer of protection can help keep their young children safe. Caregivers can achieve this reduction by buying products with neutral labeling or other packaging characteristics distinct from food-like packaging, as suggested by previous research (Basso et al., 2016; Buchmüller et al., 2022; Gibbs et al., 2005). In addition to reducing ambiguity, caregivers can add another layer of protection by purchasing products that facilitate risk perception for their children and generally reduce their attraction toward these products (e.g., household chemicals in black packaging). Furthermore, our results support the recommendation to never put household chemicals into other containers and to keep them always in their original packaging, as the original packaging provides important information for adults and children who encounter these products. In addition, our results suggest that it may be beneficial for caregivers to facilitate safe experiences with hazardous products for their children, such as by having them place dishwasher tablets in the dishwasher under supervision. This might help preschool children further improve their understanding of safety issues and reduce their risk of interacting with hazardous products (Morrongiello et al., 2014). However, these strategies should not be used in place of other recommended safety measures, such as safeguarding the household (e.g., dedicated and lockable cleaning closet) or supervising children's play. Instead, these recommendations are meant to complement these measures.

Furthermore, our findings have practical implications for manufacturers. With product design playing an important role in a saturated market, we understand that manufacturers rely on eye-catching product packaging. However, manufacturers could take a proactive position and come up with other ways to do their part to reduce the risk of unintentional poisoning with household chemicals. Finally, our findings support the current regulation by the European Commission (No. 276/2010) regarding the packaging characteristics of lamp oil and lighter fluids. However, policymakers are advised not to overregulate risks, as this can shift risks to other domains, as described by the *lulling effect* (Viscusi, 1984). For example, child-resistant packaging has been suggested to reduce caregivers' risk perceptions and their efforts to safely store household chemicals (Bearth et al., 2022; Gibbs et al., 2005). Measures should therefore focus more on information campaigns to raise awareness of the risks and hazards of household chemicals, especially among new caregivers with their first child, to ensure safe practices at home from the beginning.

5.1 | Implications for future research and limitations

The present study investigated the effect of ambiguity on preschool children's categorization ability and risk perception. Although our study provides insights into children's categorization of household chemicals, there are still open questions. In our study, children were more likely to categorize individually wrapped dishwashing tablets as edible. However, it was unclear whether the children would remain with this conclusion after they had unwrapped the dishwashing tablet. Future research could investigate whether preschool children's initial categorization of food-like household chemicals holds even after removing food-like product characteristics.

Furthermore, due to the design of this study, we could not determine how these individual risk factors (i.e., packaging, color, and scent) are weighted in young children's risk perception. Therefore, we could not draw conclusions about how a combination of these attributes influences children's risk perception (e.g., are fruity-scented products in black containers still perceived as dangerous?). Future research could design studies specifically aimed at examining the

relationship among different factors that are known to influence children's risk perception individually.

In addition, future research could explore how children categorize dangerous objects, as understanding how children categorize unfamiliar objects could provide important insights into child-safe product design and risk communication. Therefore, an approach focusing on strategies (e.g., heuristics) that children use to categorize unfamiliar objects Might be fruitful. Research on the use of heuristics in early childhood has already been done (e.g., Geurten et al., 2015; Gualtieri & Denison, 2018), and it would be interesting to see how they could be applied in the field of household chemicals. For example, simple and easy-to-understand heuristics or rules of thumb could be developed, communicated to children, and tested to determine whether they increase preschool children's safety understanding regarding household chemicals.

In general, this study enhanced our understanding of the effects of ambiguous product characteristics on children's categorization. However, these product characteristics were assessed in a laboratory setting. Although this helps to control for confounding effects and determine the effect of specific product characteristics, most unintentional injuries happen within a far more uncontrolled setting (e.g., the household; Bryant et al., 2022; Roddy et al., 2004; Simpson et al., 2009). Future research is needed to study children's categorization of household chemicals within more realistic settings or even in caregivers' homes to further improve our knowledge of the factors leading to unintentional poisonings.

6 | CONCLUSION

This study adds to the existing literature, as it systematically assessed the effects of ambiguous product characteristics on preschool children's categorization. Preschool-aged children exposed to household chemicals with food-like product characteristics can be deceived and therefore falsely categorize these dangerous products as edible. These findings highlight the responsibility of decision-makers, manufacturers, and, most importantly, caregivers because they are the ones who can directly influence the safety of children's environments through safeguarding and supervision. However, it is also the responsibility of decision-makers and manufacturers to either raise public awareness of this issue or continuously improve packaging design not only to maximize sales but also to improve their safety in everyday use.

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REFERENCES

Abdelgalil, M. S. (2016). Practices in using and handling household cleaning products in Egypt. *Tenside Surfactants Detergents*, *53*(6), 576–588. https://doi.org/10.3139/113.110452

Basso, F., Bouillé, J., Le Goff, K., Robert-Demontrond, P., & Oullier, O. (2016). Assessing the role of shape and label in the misleading packaging of food imitating products: From empirical evidence to policy recommendation. *Frontiers in Psychology*, *7*, 450. https://doi.org/10.3389/fpsyg.2016.00450

Basso, F., Robert-Demontrond, P., Hayek, M., Anton, J.-L., Nazarian, B., Roth, M., & Oullier, O. (2014). Why people drink shampoo? Food imitating products are fooling brains and endangering consumers for marketing purposes. *PLoS ONE*, *9*(9), e100368. https://doi.org/10.1371/journal.pone.0100368

Bearth, A., Bosshart, N., Wermelinger, S., Daum, M., & Siegrist, M. (2022). Household chemicals and pre-schoolers: Caretakers' beliefs and perspectives on risks and responsibilities. *Safety Science*, *154*, 105864. https://doi.org/10.1016/j.ssci.2022.105864

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

Bearth, A., & Siegrist, M. (2019). Situative and product-specific factors influencing consumers' risk perception of household cleaning products. *Safety Science*, *113*, 126–133. https://doi.org/10.1016/j.ssci.2018.11.023

Berry, J. W., & Schwebel, D. C. (2009). Configural approaches to temperament assessment: Implications for predicting risk of unintentional injury in children. *Journal of Personality*, *77*(5), 1381–1410. https://doi.org/10.1111/J.1467-6494.2009.00586.X

Bosshart, N., Bearth, A., Wermelinger, S., Daum, M., & Siegrist, M. (2022). Seeing household chemicals through the eyes of children—Investigating influential factors of preschoolers' perception and behavior. *Journal of Safety Research*, *83*, 400–409. https://doi.org/10.1016/j.jsr.2022.09.015

Bryant, L., Morrongiello, B. A., & Cox, A. (2022). Parents' home-safety practices to prevent injuries during infancy: From sitting to walking independently. *Journal of Child and Family Studies*, *31*(5), 1–11. https://doi.org/10.1007/s10826-022-02320-2

Buchmüller, K., Bearth, A., & Siegrist, M. (2022). The influence of packaging on consumers' risk perception of chemical household products. *Applied Ergonomics*, *100*, 103676. https://doi.org/10.1016/J.APERGO.2021.103676

Colunga, E., & Smith, L. B. (2005). From the lexicon to expectations about kinds: A role for associative learning. *Psychological Review*, *112*(2), 347–382. https://doi.org/10.1037/0033-295X.112.2.347

Gelman, S. A., & Meyer, M. (2011). Child categorization. *WIREs Cognitive Science*, *2*(1), 95–105. https://doi.org/10.1002/wcs.96

Geurten, M., Willems, S., Germain, S., & Meulemans, T. (2015). Less is more: The availability heuristic in early childhood. *British Journal of Developmental Psychology*, *33*(4), 405–410. https://doi.org/10.1111/BJDP.12114

Gibbs, L., Waters, E., Sherrard, J., Ozanne-Smith, J., Robinson, J., Young, S., & Hutchinson, A. (2005). Understanding parental motivators and barriers to uptake of child poison safety strategies: A qualitative study. *Injury Prevention*, *11*(6), 373–377. https://doi.org/10.1136/ip.2004.007211

Gualtieri, S., & Denison, S. (2018). The development of the representativeness heuristic in young children. *Journal of Experimental Child Psychology*, *174*, 60–76. https://doi.org/10.1016/j.jecp.2018.05.006

Hoffman, A. C., Salgado, R. V., Dresler, C., Faller, R. W., & Bartlett, C. (2016). Flavour preferences in youth versus adults: A review. *Tobacco Control*, *25*(Suppl 2), ii32–ii39. https://doi.org/10.1136/tobaccocontrol-2016-053192

Kamboj, A., Spiller, H. A., Casavant, M. J., Kistamgari, S., Chounthirath, T., & Smith, G. A. (2020). Household cleaning product-related ocular exposures reported to the United States poison control centres. *Eye*, *34*(9), 1631–1639. https://doi.org/10.1038/s41433-019-0691-9

Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development*, *8*(3), 291–318. https://doi.org/10.1016/S0885-2014(93)80003-C

Marshall, D., Stuart, M., & Bell, R. (2006). Examining the relationship between product package colour and product selection in preschoolers. *Food Quality and Preference*, *17*(7–8), 615–621. https://doi.org/10.1016/J.FOODQUAL.2006.05.007

Martin, C. L., Ruble, D. N., & Szkrybalo, J. (2002). Cognitive theories of early gender development. *Psychological Bulletin*, *128*(6), 903–933. https://doi.org/10.1037/0033-2909.128.6.903

McKenzie, L. B., Ahir, N., Stolz, U., & Nelson, N. G. (2010). Household cleaning product-related injuries treated in US emergency departments in 1990–2006. *Pediatrics*, *126*(3), 509–516. https://doi.org/10.1542/peds.2009-3392

Miller, M. A., Levsky, M. E., Masneri, D. A., & Borys, D. (2006). 268: FABULOSO®: A cleaning product that tastes and smells good enough to drink. *Annals of Emergency Medicine*, *48*(4), 81. https://doi.org/10.1016/j.annemergmed.2006.07.725

Morrongiello, B. A., McArthur, B. A., & Bell, M. (2014). Managing children's risk of injury in the home: Does parental teaching about home safety reduce young children's hazard interactions? *Accident Analysis & Prevention*, *71*, 194–200. https://doi.org/10.1016/j.aap.2014.04.016

Morrongiello, B. A., & Sedore, L. (2005). The influence of child attributes and social-situational context on school-age children's risk taking behaviors that can lead to injury. *Journal of Applied Developmental Psychology*, *26*(3), 347–361. https://doi.org/10.1016/j.appdev.2005.02.003

Owen, K., & Barnes, C. (2021). The development of categorization in early childhood: A review. *Early Child Development and Care*, *191*(1), 13–20. https://doi.org/10.1080/03004430.2019.1608193

Pauli, L. (2018). *Richtig giftig [Really toxic]* (C. De Weck, Illus.). Atlantis-Verlag.

Pollack-Nelson, C., & Drago, D. A. (2002). Supervision of children aged two through six years. *Injury Control and Safety Promotion*, *9*(2), 121–126. https://doi.org/10.1076/icsp.9.2.121.8696

R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rakison, D. H., & Lupyan, G. (2008). ABSTRACT. *Monographs of the Society for Research in Child Development*, *73*(1), vii–vii. https://doi.org/10.1111/j.1540-5834.2008.00454.x

Roddy, M. E., O'Rourke, K. M., & Mena, K. (2004). Factors associated with increased risk for acute unintentional childhood poisoning among children living on the U.S.-Mexico border. *International Quarterly of Community Health Education*, *23*(4), 295–309. https://doi.org/10.2190/1K4P-Q3V2-KFQ7-PNWL

Rosenman, K. D., Reilly, M. J., & Wang, L. (2021). Calls to a state poison center concerning cleaners and disinfectants from the onset of the COVID-19 pandemic through April 2020. *Public Health Reports*, *136*(1), 27–31. https://doi.org/10.1177/0033354920962437

Schneider, K. C. (1977). Prevention of accidental poisoning through package and label design. *Journal of Consumer Research*, *4*(2), 67–74. https://doi.org/10.1086/208681

Schwebel, D. C., Evans, W. D., Hoeffler, S. E., Marlenga, B. L., Nguyen, S. P., Jovanov, E., Meltzer, D. O., & Sheares, B. J. (2017). Unintentional child poisoning risk: A review of causal factors and prevention studies. *Children's Health Care*, *46*(2), 109–130. https://doi.org/10.1080/02739615.2015.1124775

Schwebel, D. C., Wells, H., & Johnston, A. (2015). Children's recognition of dangerous household products: Child development and poisoning risk. *Journal of Pediatric Psychology*, *40*(2), 238–250. https://doi.org/10.1093/jpepsy/jsu088

Siegrist, M., & Árvai, J. (2020). Risk perception: Reflections on 40 years of research. *Risk Analysis*, *40*(S1), 2191–2206. https://doi.org/10.1111/risa.13599

Simpson, J. C., Turnbull, B. L., Ardagh, M., & Richardson, S. (2009). Child home injury prevention: Understanding the context of unintentional injuries to preschool children. *International Journal of Injury Control and Safety Promotion*, *16*(3), 159–167. https://doi.org/10.1080/17457300903135636

Sloutsky, V. M., & Fisher, A. V. (2011). The development of categorization. In B. Ross (Ed.), *Psychology of learning and motivation—Advances in research and theory* (Vol. 54, pp. 141–166). Academic Press. https://doi.org/10.1016/B978-0-12-385527-5.00005-X

Smolinske, S. C., & Kaufman, M. M. (2007). Consumer perception of household hazardous materials. *Clinical Toxicology*, *45*(5), 522–525. https://doi.org/10.1080/15563650701354192

Spencer, J., Quinn, P. C., Johnson, M. H., & Karmiloff-Smith, A. (1997). Heads you win, tails you lose: Evidence for young infants categorizing mammals by head and facial attributes. *Early Development and Parenting*, *6*(3–4), 113–126. https://doi.org/10.1002/(SICI)1099-0917(199709/12)6:3/4

Tox Info Suisse. (2022). *Annual report 2021*. https://www.toxinfo.ch/jahresberichte-neu_en

Valentin, D., & Chanquoy, L. (2012). Olfactory categorization: A developmental study. *Journal of Experimental Child Psychology*, *113*(3), 337–352. https://doi.org/10.1016/J.JECP.2012.05.007

Viscusi, W. K. (1984). The lulling effect: The impact of child-resistant packaging on aspirin and analgesic ingestions. *The American Economic Review*, *74*(2), 324–327. http://www.jstor.org/stable/1816378

Walsh, L. M., Toma, R. B., Tuveson, R. V., & Sondhi, L. (1990). Color preference and food choice among children. *The Journal of Psychology*, *124*(6), 645–653. https://doi.org/10.1080/00223980.1990.10543258

Weiler, S., & Kupferschmidt, H. (2020). Vergiftungen in der Schweiz [Poisonings in Switzerland]. *Schweizerische Ärztezeitung*, *101*(4), 88–92. https://doi.org/10.4414/saez.2020.18490

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