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Are additives unnatural? Generality and mechanisms of additivity dominance

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Abstract

Naturalness is important and valued by most lay Western individuals. Yet, little is known about the lay meaning of "natural". We examine the phenomenon of additivity dominance: adding something to a natural product (additive) reduces naturalness more than removing an equivalent entity ("subtractive"). We demonstrate additivity dominance for the first time using equivalent adding and subtracting procedures. We find that adding something reduces naturalness more than removing the *same* thing (e.g., adding pulp to orange juice reduces naturalness more than removing pulp from orange juice; Study 1); an organism with a gene added is less natural than one with a gene removed (Study 2); and framing a product as an additive (versus as a subtractive) reduces naturalness (Study 3). We begin to examine accounts of additivity dominance. We find that it is not due to the connotations of the word "additive" (Study 4). However, data are consistent with an extra processing account — where additives involve more processing (extracting and adding) than subtractives (only removing) — and with a contagion account — where adding is more contaminating than removing (Study 5).

Keywords: natural, process, contagion, additivity dominance, additive

1 Introduction

For many in the Western world, naturalness is an important and valued concept (Rozin et al., 2004; Rozin, Fischler & Shields-Argeles, 2012). Consumers search for and prefer products that are labeled as "natural"[1], especially foods (Rock, 2016). In fact, between 2003 and 2010 "natural" was the second-most common claim made by new food and beverage products (USDA, 2017). Of course, individuals sometimes prefer unnatural products when those products are better on other attributes (e.g., prefer an unnatural medicine because it is more potent). However, most people prefer a natural product when other attributes — such as price, potency, and taste — are held constant (Rozin et al., 2004; Scott, Rozin, & Small, 2017). In spite of this widespread natural preference, little attention has been paid to what natural means to the lay individual. In the present research, we investigate one key feature of the lay meaning of natural: the absence of additives.

Prior work suggests that there are at least two defining features of naturalness: absence of human processing or interventions and absence of additives. In open-ended questions with American and European respondents, the most common definitions of natural were "no processing" (e.g., not altered, not touched by humans) and "no additives" (e.g., no chemicals, nothing added; Rozin et al., 2012). Some research has been devoted to understanding how the presence and type of human processing alters perceptions of naturalness. This work demonstrates, for example, that chemical transformations are less natural than physical transformations (Rozin, 2005; Evans, de Challemaison & Cox, 2010); mixing different entities is less natural than mixing like entities (Rozin, 2005; Evans et al., 2010); and genetic modification is particularly unnatural (Rozin, 2005; Tenbült, de Vries, Dreezens & Martijn, 2005).

Less research has been devoted to understanding the psychology of additives. We hypothesize the presence of additives[2], one result of human processing, reduces naturalness more than "subtractives" (removals of some part of a natural product). We call this phenomenon additivity dominance (Rozin, Fischler & Shields-Argeles, 2009). For example, milk with all of the fat removed is viewed to be more natural than milk with a small amount of natural vitamin D added, even though the former manipulation much more substantially alters the content of the milk (Rozin et al., 2009). The word "additive" is lexicalized in many more languages than the logically equivalent word "subtractive," indicating additives may be more salient than subtractives (Rozin et al.,

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[1]Currently, "natural" is not legally defined by the U.S. Food and Drug Administraton (FDA). However, as a result of consumer petitions, the FDA has begun the process of codifying the usage of the term "natural" (Aubrey, 2015).

[2]In the present paper, "additives" refer to the lay meaning of additives (any addition to a product or entity) as opposed to the FDA definition (which has other technical requirements).

2009). While this body of evidence is suggestive, only one paper has directly examined the asymmetry between adding and removing. Moreover, to our knowledge, no prior work has systematically examined whether removing something (e.g., fat from milk) is less natural than adding the exact same thing (e.g., fat to milk) or why such an effect might occur.

We experimentally test whether additivity dominance occurs, using purer examples than the previous literature. We expect that adding something will reduce naturalness more than removing the same thing. Furthermore, we test the generality of additivity dominance across many types of products and for many types of additives. We examine two domains where this type of asymmetry (adding versus removing the same thing) exists in the real world: beverages and genetic modification.

Additivity Dominance for Beverages Hypothesis. Additivity dominance occurs for beverages, whether modified by physical or chemical processes, such that products with ingredients added are rated as less natural than products with the *same* ingredients removed.

Additivity Dominance for Genetic Modification Hypothesis. Additivity dominance occurs for genetically modified organisms, such that organisms with genes added are rated as less natural than organisms with genes removed.

Another way to examine whether additives are thought to be especially unnatural, more so than subtractives, is to frame the same product in different ways. In particular, we expect framing the same product as a potential additive reduces naturalness.

Additivity Dominance Framing Hypothesis. Framing a product as an additive (versus a subtractive) reduces its perceived naturalness.

We also aim to investigate the reasons why additivity dominance occurs. We present three possible accounts for additivity dominance.

We call the first account the connotation account. Additives may be considered particularly harmful to naturalness because of the connotations of the word "additive." According to this account, when the same product is described as having an "additive" as opposed to being "fortified" or "supplemented" (which carry more positive connotations), the additive effect should be enhanced.

Connotation Account Hypothesis. Products described as having an "additive" (a negatively valenced synonym) are rated as less natural than the same products described as being "fortified" or "supplemented" (more positively valenced synonyms), where the substance added is the same in all three cases.

We call the second account the extra processing account. Rozin (2005) found that processing substantially reduces naturalness. Additives are a salient manifestation of processing. Additives must be 1) obtained (often by a process, such as extraction) and 2) added to a product. Subtractives, on the other hand, need only be removed. If individuals view additives as involving extra human processing, then additives should be especially detrimental to naturalness. According to this account, two final products with the same content will be judged differently depending on how the additive was added (i.e., the processing history). For example, adding one unit of an additive in one process (less processing history) is more natural than adding 1/3 a unit three times in three separate processes (more processing history).

Extra Processing Account Hypothesis. Additivity dominance will be greater when the product contains an additive with more processing history, controlling for the content of the product.

We call the third account the contagion account. This account arises from the contagion law of sympathetic magic (Frazer, 1890/1922/1959; Mauss, 1902/1972; Rozin & Nemeroff, 2002), a lay belief that once a source entity comes into contact with a target entity, the source transfers its essence and properties to the target. In other words, "once in contact, always in contact." Rozin, Millman & Nemeroff (1986) show that magical contagion beliefs, initially thought to be limited to traditional cultures, are very common in modern-day Americans. In the case of additives, lay beliefs may hold that adding foreign content involves a transfer of some unnatural quality from the source (additive) to the target (product). This account is related to purity, a frequent free associate of natural (Rozin et al., 2012). Additives contaminate a product with a foreign essence, thereby reducing purity. One principle of contagion is dose insensitivity, where contagion increases minimally across different amounts of contact (Rozin & Nemeroff, 2002). According to this account, naturalness should be sensitive to the presence versus absence of an additive, but insensitive to the dose of the additive. Generalizing dose insensitivity to processing, we should also find that once processing has occurred, additional amounts of it should not matter much.

Contagion Account's Dose Insensitivity Hypothesis. Increasing the dose of an additive has small effects on the naturalness of the product.

Contagion Account's Processing Insensitivity Hypothesis. Increasing the amount of the same process has small effects on the naturalness of a product.

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The current studies aim to clarify and begin to explain additivity dominance. In Study 1, testing the additivity dominance for beverages hypothesis, we investigate a set of pure cases of additivity dominance by comparing naturalness ratings of beverages with something added to beverages with the same thing removed. In Study 2, testing the additivity dominance for genetic modification hypothesis, we examine whether an organism with an added gene is less natural than an organism with a deleted gene. In doing so, we extend additivity dominance to a new domain. In Study 3, testing the additivity dominance framing hypothesis, we examine whether framing a product as a potential additive (versus a subtractive) reduces its naturalness. In Studies 4A and 4B, we test the connotation account hypothesis; we examine whether products are rated as particularly unnatural when they are described with a negatively valenced synonym ("additive") as compared to a positively valenced synonym ("supplemented" or "fortified"). In Study 5, we test hypotheses from the extra processing and contagion accounts; we examine the impact of tripling the additive's dose or processing history.

2 Study 1

Study 1 tests the additivity dominance for beverages hypothesis. We expect that beverages are judged to be more natural when a component is removed from the beverage than when the *exact same* component is added to the beverage.

2.1 Method

2.1.1 Subjects

One hundred fifty-eight University of Pennsylvania undergraduate students completed a web-based survey in exchange for class credit in November 2011. In this and all following studies with the 0 to 100 perceived naturalness scale, we excluded subjects who gave inconsistent responses to the scale training (see details below). In this study, six subjects were excluded based on the scale training criteria, leaving a final sample of 152 subjects (56.6% female, M_{age}=19.4, *SD*=1.4).

2.1.2 Scale training

In this and all following studies measuring perceived naturalness on a 0 to 100 scale, subjects read the below scale training instructions (adapted from Rozin, 2005):

> Please rate the following choices in terms of how natural you believe they are. The scale runs from 0, which is completely unnatural, to 100, which is completely natural. For this scale and all scales with a slider, you must move the slider for your answer to register. Even if you want your answer to be 50, you still have to move the slider away and back to 50 for your answer to count.
>
> How natural are the following items?
>
> ______ A tree on a mountain peak in the Andes that has never been climbed
>
> ______ A plastic toy model of a pistol
>
> ______ A hard boiled egg
>
> The tree should get a rating at or near 100, the plastic toy model of a pistol should be at or near zero, and the egg should be somewhere in between. Please check to make sure this is true for your ratings, and if not, think a bit before going on.

In this and following studies, we excluded subjects who rated the tree as less natural than the egg or the egg as less natural than the pistol[3].

2.1.3 Procedure

After the scale training, subjects rated the naturalness of fourteen beverages. There were four baseline beverages — organic and commercially produced milk and orange juice. Additionally, there were five additive-subtractive beverage pairs (ten beverages total): organic milk with a) 100% more fat, b) 100% less fat, c) 100% more sugar, d) 100% less sugar, e) 50% more calcium, f) 50% less calcium, and organic orange juice with g) 100% more pulp, h) 100% less pulp, i) 100% more vitamin C, j) 100% less vitamin C.

An additive drink was described as follows: "organic high sugar milk (which is organic whole milk with double the sugar content, made by adding the sugar removed from another batch of organic whole milk in the process of making that batch low sugar milk)." A subtractive drink was described as follows: "organic low sugar milk (which is organic whole milk with all the sugar removed)."

These questions were embedded on one page in a larger survey on preferences for natural products. Questions about milk products were presented in one block together, and questions about orange juice were presented in a different block together. Subjects first answered questions about milk and then questions about orange juice. Beverages within each block were presented in randomized order[4].

[3]We report in the Supplement a replication of this study where half or subjects complete this scale training and half do not, through random assignment. Scale training had no main or interactive effects on naturalness ratings. In the no scale training condition, subjects showed significant additivity dominance for three pairs (milk with sugar, milk with calcium, orange juice with pulp, *ps*<.008), directional additivity dominance for one pair (milk with fat, *p*=.103) and a reversal for one pair (milk with calcium, *p*=.005).

[4]Throughout the paper, "randomized order" indicates randomized for each subject

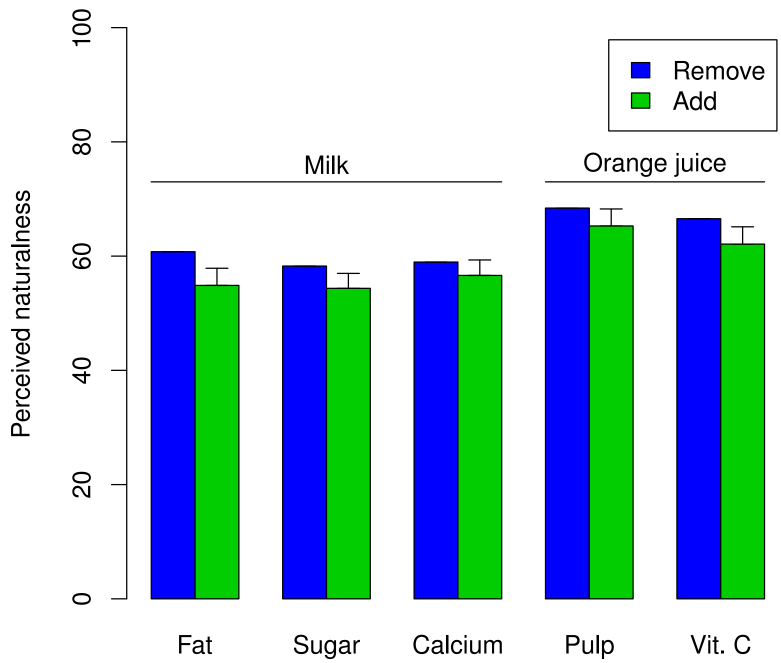

FIGURE 1: Perceived naturalness of additive (versus subtractive) versions of milk and orange juice in Study 1. Because the t-test for each pair is a within-subjects (i.e., paired samples) t-test, the error bars are 95% confidence intervals of the difference between add and remove (as opposed to 95% confidence intervals of the mean).

2.2 Results

2.2.1 Are beverages with something added less natural than those with the same thing removed?

We conducted a 2 (Process: Added, Subtracted) x 5 (Beverage Pairs: Milk with Fat, Milk with Sugar, Milk with Calcium, Orange Juice with Pulp, Orange Juice with Vitamin C) repeated measures ANOVA on the rated naturalness of the five additive-subtractive beverage pairs (ten beverages total). Drinks with additives were rated as less natural than those with subtractives ($F(1,151)=16.57$, $p < 0.001$, $\eta_p^2=0.10$), beverage pairs varied in naturalness ($F(4,604)=28.46$, $p<0.001$, $\eta_p^2=0.16$), and the additive effect did not depend on the beverage pair (no interaction, $F(4,604)=1.09$, $p=.360$). Additive beverages were rated as significantly less natural in four out of five beverage pair comparisons (see Figure 1; d_{RM}[5] from .13 to .30; see Table S2 in Supplement for descriptive statistics and t-tests for each pair).

2.2.2 How much does any intervention (adding or removing) affect naturalness relative to no intervention?

As ancillary measures, we asked subjects to rate the naturalness of organic milk ($M=91.13$, $SD=13.88$), organic orange juice ($M=91.84$, $SD=15.20$), conventionally produced milk ($M=47.61$, $SD=28.21$) and conventionally produced orange juice ($M=46.07$, $SD=29.07$). These measures illustrate that though additivity dominance is reliable, it is small compared to other effects. Conventional processing versus organic processing reduced naturalness by an average of 44.65 points. Removing something versus no intervention reduced naturalness by an average of 28.82 points, and adding something (versus removing something) reduced naturalness by another 3.94 points (32.76 points compared to no intervention).

2.3 Discussion

Consistent with the additivity dominance for beverages hypothesis, Study 1 finds that consumers perceive a product with something added as less natural than one with the same thing removed. We also find additivity dominance for both healthy (e.g., vitamin C) and unhealthy (e.g., sugar) additives.

3 Study 2

Study 2 tests the additivity dominance for genetic modification hypothesis. To examine the generality of additivity dominance, we move to a very different domain — genetic modification of plants and animals. We expect additivity dominance to extend to the domain of genetic modification, such that organisms with a gene added are less natural than those with a gene removed.

[5]Throughout the paper, d_{RM} denotes the repeated-measures Cohen's d, calculated as the mean difference score divided by the standard deviation of difference scores. See Morris & DeShon (2002) for details.

3.1 Method

One hundred ninety-five University of Pennsylvania undergraduate students completed a web-based survey in exchange for class credit in March 2012. Four subjects were excluded based on inconsistent responses in scale training (see Study 1 scale training for more information), resulting in a final sample of 191 subjects (59.2% female, M_{age}=19.6, *SD*=1.7).

Subjects rated the naturalness of cocker spaniel dogs and of corn plants. The scenario read as follows (emphasis in original):

> Imagine that, through new innovation, scientists have found a way to insert or remove a gene. The scientists add or remove genes in cocker spaniel dogs and in corn plants when the organisms are fertilized eggs. When scientists add gene A to a cocker spaniel or corn plant, they are adding the exact same gene A, extracted from yeast cells. In all cases, the only effect of the genetic modification is to make the cocker spaniel's fur lighter in color, and to make the corn lighter in color
>
> How natural are the following organisms?

Dogs and corn plants either had a) "no genes inserted or removed", b) "additional gene A inserted by a scientist", c) "original gene B removed by a scientist", or d) "original gene B replaced with new gene A by a scientist". Thus, subjects rated eight exemplars in a 2 (Organism: Dog, Corn) x 4 (Modification: None, Gene Added, Gene Removed, Gene Replaced) design. The eight exemplars were presented on one page in a randomized order. This page was embedded in a larger survey on natural preference. Our primary comparison was gene added exemplars versus gene removed exemplars, and no modification exemplars were included to give a sense of the impact of any genetic modification. Gene replaced exemplars were included as an exploratory measure.

3.2 Results

3.2.1 Are organisms with genes added less natural than those with genes removed?

We conducted a 2 (Organism: Dog, Corn) x 2 (Modification: Gene Added, Gene Removed) repeated measures ANOVA on naturalness ratings. Adding a gene reduced naturalness more than removing one ($F(1,190)$=10.91, p=0.001, η_p^2=0.05), corn plants and dogs did not reliably differ in naturalness ($F(1,190)$=2.75, p=.099), and the additive effect did not differ between corn plants and dogs (no interaction between additive and organism, $F(1,190)$=0.66, p=.417). Follow-up, two-tailed t-tests indicated that a dog with a gene added was less natural than one with a gene removed ($M_{\textit{dog, gene added}}$=40.61, *SD*=23.47, $M_{\textit{dog, gene removed}}$=43.18, *SD*=23.72, $t(190)$=2.53, p=0.012, d_{RM}=0.18) and a corn plant with a gene added was less natural than one with a gene removed ($M_{\textit{corn, gene added}}$=41.34, *SD*=23.68, $M_{\textit{corn, gene removed}}$=44.65, *SD*=23.57, $t(190)$=3.36, p=0.001, d_{RM}=0.24).

3.2.2 How much does any genetic modification (adding or removing) affect naturalness compared to no genetic modification?

As ancillary measures, we asked subjects to rate the naturalness of a dog with no genetic modification (*M*=87.50, *SD*=22.44), a corn plant with no genetic modification (*M*=89.60, *SD*=19.25), a dog with a gene replaced (*M*=40.03, *SD*=23.49), and a corn plant with a gene replaced (*M*=41.48, *SD*=24.21). As in Study 1, these measures illustrate that additivity dominance is reliable but small compared to other effects. On average, removing a gene reduced naturalness by 44.64 points compared to not intervening, and adding a gene reduced naturalness by 2.94 points compared to removing a gene (47.58 points compared to no intervention).

3.3 Discussion

Consistent with the additivity dominance for genetic modification hypothesis, Study 2 demonstrates that organisms with genes added are perceived as less natural than those with genes removed.

4 Study 3

Study 3 tests the additivity dominance framing hypothesis. We expect that framing the same product as a potential additive reduces its naturalness, in comparison to a subtractive framing.

4.1 Method

Two hundred three American subjects completed a web-based survey on Amazon's Mechanical Turk in exchange for monetary compensation in July 2013. Twelve subjects were excluded based on inconsistent responses in scale training (see Study 1 scale training for more information) resulting in a final sample of 191 subjects (48.2% female, M_{age}=32.0, *SD*=11.7).

Subjects rated naturalness of four items — peanut oil, orange pulp, fat, and calcium. Each item was rated twice: once when the item was framed as a subtractive and once framed as an additive. The subtractive framings of these items were: "peanut oil that was removed from peanut butter", "yogurt fat that was removed from yogurt", "orange pulp that was removed from orange juice", and "calcium that was removed from milk". The additive framings of these items were:

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"peanut oil that was removed from peanut butter and is going to be added to another batch of peanut butter", "yogurt fat that was removed from yogurt and is going to be added to another batch of yogurt", "orange pulp that was removed from orange juice and is going to be added to another batch of orange juice", and "calcium that was removed from milk and is going to be added to another batch of milk."

Subjects were randomly assigned to either view a page with four items in the additive framing and then a page with four items in the subtractive framing or vice versa. In between viewing the additive and subtractive framings, subjects completed an unrelated study. On each page, the order of the four items was randomized.

4.2 Results

The order of the framing manipulation (additive items first versus subtractive items first) did not have any main or interactive effects, so we collapse across order.[6] We conducted a 2 (Framing: Additive, Subtractive) x 4 (Item: Oil, Pulp, Fat, Calcium) repeated measures ANOVA on naturalness ratings. Framing items as potential additives reduced naturalness ($F(1{,}190)=37.03$, $p<.001$, $\eta_p^2=.16$), items varied in naturalness ($F(3{,}570)=39.70$, $p<.001$, $\eta_p^2=.17$), and there was no framing by item interaction ($F(3{,}570)=1.46$, $p=.225$). Additive framing (versus subtractive framing) significantly reduced naturalness in the paired comparisons for all four items (see Figure 2; d_{RM} from .32 to .46; see Table S3 in Supplement for descriptive statistics and t-tests for each pair).

4.3 Discussion

Consistent with the additivity dominance framing hypothesis, Study 3 finds that merely describing products as potential additives reduces naturalness, for both healthy (e.g., calcium) and unhealthy (e.g., oil) products. In the next studies, we begin to examine different accounts of additivity dominance.

5 Study 4A

In Study 4A, we examine a connotation account of additivity dominance: that additives are perceived as unnatural because the connotations of "additive" are negative. In the connotation account hypothesis, we predict that describing a substance as having an "additive" (negatively valenced term) versus being "fortified" or "supplemented" (more positively valenced terms) reduce perceived naturalness of the product to which it was added.

[6]There was one exception. In a 2 (Framing: Additive, Subtractive) x 4 (Item: Oil, Pulp, Fat, Calcium) x 2 (Order: Additive First, Subtractive First) mixed ANOVA, the main effect of order and interactions with order were not significant (*p*s >.1) except a three-way interaction between framing, item, and order ($p=.013$). This interaction was driven by the differences between additive and subtractive framings for calcium and yogurt fat being particularly large when additive came first. Because this interaction was small and not predicted a priori, we collapse across order.

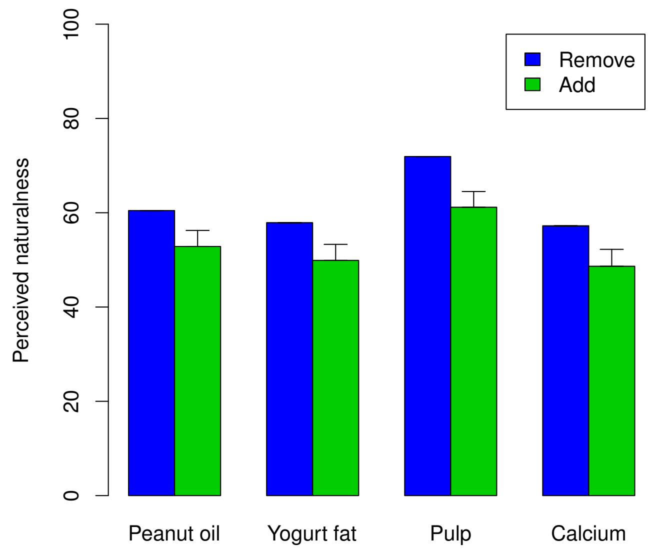

Figure 2: Perceived naturalness of additive (versus subtractive) framings of four items in Study 3. Because the t-test for each pair is a within-subjects (i.e., paired samples) t-test, the error bars are 95% confidence intervals of the difference between add and remove (as opposed to 95% confidence intervals of the mean).

5.1 Method

Two hundred one American subjects completed a web-based survey on Amazon's Mechanical Turk in exchange for monetary compensation in July 2013. Eight subjects were excluded based on inconsistent responses in scale training (see Study 1 scale training for more information) resulting in a final sample of 193 subjects (50.3% female, $M_{\text{age}}=33.1$, $SD=12.0$).

In the first part of the survey subjects completed a pretest to assess whether different synonyms had different valence. There were three blocks — an additive block, a fortified block, and a supplemented block. Subjects completed all three blocks in a randomized order. Within each block, subjects first generated three free associates for the word (e.g., three free associates for additive in the additive block), and then, on the next page, subjects rated the valence of each free associate as positive, negative, or neutral.

In the second part of the survey, subjects were randomly assigned to one of three conditions: additive description, fortified description, or supplemented description. Subjects rated the naturalness of six products: a) orange juice, b) orange juice with 50% extra pulp, c) peanut butter, d) peanut butter with 50% extra fat, e) milk, and f) milk with 50%

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Table 1: Perceived naturalness of products described by synonyms with different valence in Study 4a.

Word	Mean valence score (s.d.)	Mean rating for orange juice with pulp added (s.d.)	Mean rating for peanut butter with fat added (s.d.)	Mean rating for milk with calcium added (s.d.)
Additive	−1.02 (1.85)	59.66 (23.94)	47.80 (25.29)	54.31 (25.73)
Fortified	1.83 (1.36)	52.15 (26.86)	39.05 (25.74)	48.46 (24.72)
Supplemented	1.67 (1.58)	55.04 (24.83)	45.19 (23.05)	53.72 (21.85)

Note. Valence of free associates to a synonym is displayed in column 2 and naturalness ratings of different products depending on the synonym used to describe the additive are displayed in columns 3 through 5.

extra calcium. Results for products without additives are not central to our hypotheses, and are not discussed further. Product descriptions varied depending on the subjects' condition. For example, a subject in the additive condition would have rated: "Orange juice with a pulp additive (which is orange juice with 50% extra pulp, made by adding pulp removed from another batch of orange juice)." A subject in the fortified or supplemented condition would have read the same description, except that it started with "Pulp-fortified orange juice (which is. . . " or "Pulp-supplemented orange juice (which is. . . " respectively. All six products were presented on one page in a randomized order.

5.2 Results

5.2.1 Do synonyms vary in valence?

We assessed whether additive was a more negatively valenced synonym. Subjects' indicated their free associates were positive, neutral, or negative, and we used these ratings to create valence scores. Each free associate was assigned a score of +1 for positive, 0 for neutral, and −1 for negative. The three free associates were then summed for each word, such that subjects' valence scores for a given word ranged from +3 to −3.

Synonyms did differ substantially, such that the "additive" synonym was more negatively valenced than other synonyms. In a repeated measures ANOVA, subjects' valence scores differed for the three words (F(2,384)=223.60, p<0.001, η_p^2=0.54). In follow-up two-tailed paired t-tests, additive valence was more negative than fortified valence and supplemented valence (additive versus fortified, t(192)=17.54, p<0.001, d_{RM}=1.26; additive versus supplemented, t(192)=16.98, p<0.001, d_{RM}=1.22). Fortified and supplemented valence did not differ (t(192)=1.18, p=.239). Means and standard deviations of valence scores are displayed in Table 1.

5.2.2 Do negatively valenced synonyms reduce naturalness?

Next, naturalness ratings were examined. According to a connotation account hypothesis, the additive description should produce lower naturalness scores than other descriptions because it is more negatively valenced. We conducted a 3 (Description: Additive, Fortified, Supplemented) by 3 (Item: Orange Juice with Pulp, Peanut Butter with Fat, Milk with Calcium) mixed ANOVA on naturalness ratings, with the first factor between-subjects and the second factor within-subjects. Contrary to the connotation account hypothesis, describing an item using different synonyms did not reliably alter naturalness ratings (F(2,190)=2.14, p=.121). Additionally, items varied in naturalness (F (2, 380)=25.96, p<0.001, η_p^2=0.12), and there was no interaction between item and description (F(4,380)=0.37, p=.834).

Opposite to the prediction of the connotation account, in follow-up t-tests the additive description directionally *increased* naturalness for all six pairwise comparisons. In one case, this difference was significant (additive description was rated as more natural than fortified description of peanut butter; t(134)=2.00, p=.048, d=.34). Means and standard deviations of naturalness ratings are displayed in Table 1. For full information on the t-tests for each pairwise comparison, see Tables S4–S6 in the Supplement.

5.3 Discussion

Describing a product as having an "additive" (negative connotation) did not reduce perceived naturalness as a connotation account would predict. In fact, it directionally increased perceived naturalness. This data is inconsistent with the connotation account of additivity dominance. This result is surprising to us, since a negative descriptor (additive) should intuitively act, if anything, to decrease perceptions of a related positive feature (natural). This surprising finding motivated our next study.

6 Study 4B

Study 4A finds that "orange juice with a pulp additive" and "pulp-fortified orange juice" are viewed as similar in naturalness, even though people rate the word "additive" as much more negatively valenced than the word "fortified". One possibility is that additive is more negative than fortified because the two words make different examples psychologically accessible. Additives could make examples like preservatives and high fructose corn syrup accessible, whereas fortifications and supplements could make examples like vitamins accessible. When we control for these denotations in Study 4A by specifying the content of the additive (e.g., pulp), the connotations of additive versus fortified versus supplement have no effect on naturalness.

In Study 4B, we aim to test this account. We examine whether respondent-generated exemplars of "additives," "fortifiers," and "supplements" differ in valence, healthfulness, and naturalness. We expect that the psychologically accessible (i.e., easily generated) exemplars of additives will be more negative, less healthy, and less natural, consistent with findings in Study 4A. If so, the seeming contradiction between the valence and naturalness ratings in Study 4A can be interpreted to indicate that connotation (valence) does not affect naturalness ratings, once controlling for subtly different denotations (i.e., the content of the additive, such as "pulp").

6.1 Method

Two hundred two American subjects completed a web-based survey on Amazon's Mechanical Turk in exchange for monetary compensation (46.5% female, M_{age}=37.3, SD=13.6), in August 2013.

Subjects were presented with each word (in the noun form) — additive, fortifier, and supplement — and asked to generate three examples per synonym in the context of food. Then, subjects went back to the examples they had generated. They rated the valence of all examples ("positive," "neutral" or "negative"), then the healthfulness of all examples ("healthy", "neutral" or "unhealthy"), and finally the naturalness of all examples ("natural", "neither natural or unnatural" or "unnatural"). All items were presented in this fixed order.

6.2 Results

Subjects rated valence, naturalness, and healthfulness of the nine examples that they had just generated (three examples each for additive, fortifier, supplement). We used these ratings to create valence, healthfulness, and naturalness mean scores for each word. Valence scores were calculated in the same manner as Study 4A. Similarly, for healthfulness scores, each subject-generated example was assigned as a score of +1 for healthy, 0 for neutral, and −1 for unhealthy, then summed (resulting in a range of +3 to −3), and for naturalness scores, each subject-generated example was assigned +1 for natural, 0 for neither natural or unnatural, and −1 for unnatural, then summed (resulting in a range of +3 to −3).

Table 2: Perceived Valence, Healthfulness, and Naturalness of subject-generated Additive, Fortifier, and Supplement examples in Study 4B.

Example	Mean valence score (s.d.)	Mean healthfulness score (s.d.)	Mean naturalness score (s.d.)
Additive	−0.68 (1.97)	−1.45 (1.48)	−0.70 (1.90)
Fortifier	2.01 (1.44)	1.94 (1.49)	1.82 (1.51)
Supplement	1.97 (1.45)	1.98 (1.46)	1.59 (1.68)

Note. Scores calculated from subjects' ratings of their own examples of additives, fortifiers, and supplements on valence, healthfulness, and naturalness are displayed. Scores range from −3 to 3.

We conducted three repeated measures ANOVAs, one each for valence scores, healthfulness scores, and naturalness scores. Valence scores differed across the three synonyms (F(2,402)=211.27, p<0.001, η_p^2=0.51), as did healthfulness scores, (F(2,402)=440.43, p<0.001, η_p^2=0.69) and naturalness scores (F(2,402)=159.36, p<0.001, η_p^2=0.44). In follow-up, two-tailed paired t-tests, additive examples were more negatively valenced, more unhealthy, and more unnatural than fortifier and supplement examples (all ps<0.001). Fortifier and supplement examples did not differ in valence, healthfulness or naturalness scores (ps > .08). The means and standard deviations of valence, healthfulness and naturalness scores are displayed in Table 2. For full information on the t-tests comparing examples from different synonyms on valence, health, and naturalness, see Tables S7–S9 of the Supplement.

6.3 Discussion

Study 4A offered data inconsistent with the connotation account. Though "additive" is more negatively valenced than "fortified" or "supplemented", "orange juice with a pulp additive" is not perceived as less natural than "pulp-fortified orange juice" or "pulp-supplemented orange juice." We reconcile this apparent contradiction in Study 4B. The synonyms elicit different psychologically accessible examples of the entity to be added. "Additive" makes negative examples like "preservatives" accessible, whereas "fortification" makes positive examples like "vitamins" accessible. When we control for these different denotations by specifying which entity has been added (as done in Study 4A, with "pulp" in the above example), connotations of the synonyms do not affect naturalness ratings

Day 1:	Create base product	Create base product	Create base product	Create base product
Day 2:	Store product	Store product	Store product	**Add 5% additive**
Day 3:	Store product	Store product	Store product	**Add 5% additive**
Day 4:	Store product	**Add 5% additive**	**Add 15% additive**	**Add 5% additive**
Day 5:	Package product	Package product	Package product	Package product

FIGURE 3: Overview of stimuli in Study 5. A summary of the information subjects received for each type of product is displayed (from left to right: No additive, Add 5% via 1 process, Add 15% via 1 process, Add 15% via 3 processes). Information in bold represents processing steps that differ from the "no additive" baseline product.

7 Study 5

Up to this point, we have presented some evidence suggesting that the connotation account is weak, at best. In Study 5 we examine the extra processing account and contagion accounts of additivity dominance. We examine the effects of tripling a dose of an additive (same processing, different content) and the effects of tripling the processing of an additive by administering it in three smaller doses, each one third of the total dose (more processing, same content). According to the extra processing account hypothesis, administering three doses, each one third of the same total amount, should notably decrease naturalness, because it represents a shift from one to three processes (more processing, same content). The contagion theory predicts that, due to dose insensitivity, tripling a dose should have minimal effect (contagion account's dose insensitivity hypothesis), as should administering the same content in three processes (contagion account's processing insensitivity hypothesis).

7.1 Method

Two hundred ten American subjects completed a web- based survey on Amazon's Mechanical Turk in exchange for monetary compensation in February 2015. Sixteen subjects were excluded based on inconsistent responses in scale training (see Study 1 scale training for more information) resulting in a final sample of 194 subjects (51.5% female, M_{age}=34.1, SD=11.3).

Subjects rated eleven beverages in a randomized order in a fully within-subjects design. Each beverage was presented on a separate page. Nine beverages followed a 3 (Beverage: Milk with Extra Calcium, Milk with Extra Fat, Orange Juice with Extra Vitamin C) x 3 (Addition: 5% More Through 1 Process, 15% More Through 1 Process, 15% More Through 3 Processes) design. For example, milk with 15% more fat through 3 processes was described as follows:

> Imagine a bottle of organic milk. The milk was produced in the following manner.
>
> Day 1: The cow was milked. The milk was placed in a large refrigeration tank and cooled to 40 degrees Fahrenheit.
>
> Day 2: Extra milk fat from another batch of organic milk was added to the refrigeration tank. The milk now contains 5% more fat than it did on day 1.
>
> Day 3: Extra milk fat from another batch of organic milk was added to the refrigeration tank. The milk now contains 5% more fat than it did on day 2.
>
> Day 4: Extra milk fat from another batch of organic milk was added to the refrigeration tank. The milk now contains 5% more fat than it did on day 3.
>
> Day 5: The milk was pumped into a plastic bottle and sealed.
>
> How natural is this bottle of organic milk (which now contains 15% more fat)?

When the additive (e.g., fat) was added through one process, then the scenario specified that milk was stored in the refrigeration tank on days 2 and 3 and the 5% or 15% additive was inserted on day 4. Subjects also rated two baseline beverages — organic milk and organic orange juice — which were described in a similar manner except that they were just stored on days 2–4. Figure 3 displays an overview of the process and content of each type of product (no additive, 5% added via 1 process, 15% added via 1 process, and 15% added via 3 processes).

7.2 Results

7.2.1 Effects of increased dosage versus processing

First, we estimate how much tripling the dose of the additive reduces naturalness. We compare cases with only one process (5% more through 1 process versus 15% more through 1 process) to estimate the effect of a 5% versus 15% dose, averaging across the beverages (i.e., milk with calcium, milk with fat, and orange juice with vitamin C). On average, adding 15% of an additive as compared to 5% of an additive reduced naturalness by 3.69 extra points on the 0 to 100 scale ($M_{5\%,\ 1\ Process}$=61.97, SD=23.61, versus $M_{15\%,\ 1\ Process}$=58.28, SD=24.83, $t(193)$=5.00, p<0.001, d_{RM}=.36; see Figure 4; see Table S10 in Supplement for descriptive statistics and t-tests for each beverage). Insofar as this difference is small, it supports both the contagion account and extra processing account.

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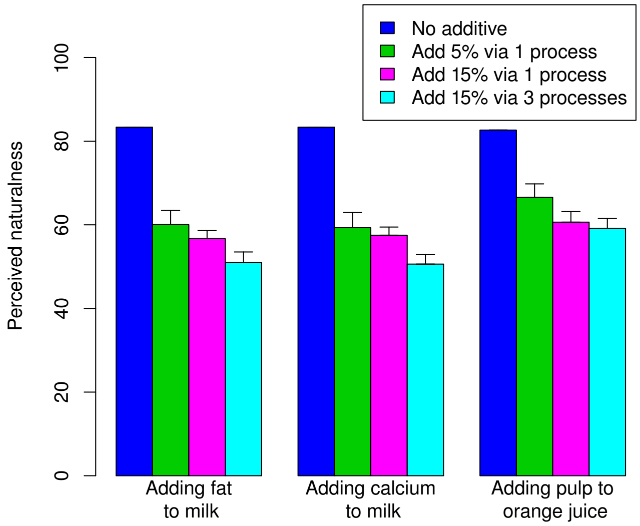

FIGURE 4: Perceived naturalness of products in Study 5. Because the experimental design was fully within-subjects, the error bars are 95% confidence intervals of the differences between the mean and the mean to the left. For example, the error bar on "add 5% via 1 process" reflects the confidence interval on the difference between no additive and adding 5% via 1 process.

Second, we estimate how much tripling the number of processes reduces naturalness. We compare cases with 15% doses (15% more through 1 process and 15% more through 3 processes) and estimate the effect of 1 versus 3 processes, averaging across the beverages (i.e., milk with calcium, milk with fat, and orange juice with vitamin C). On average, three processes as compared to one process reduced naturalness by 4.68 extra points on the 0 to 100 scale ($M_{15\%,\ 1\ Process}$=58.28, *SD*=24.83 versus $M_{15\%,\ 3\ Processes}$=53.60, *SD*=25.82, $t(193)=5.59$, $p<0.001$, d_{RM}=.40; Figure 4; see Table S11 in Supplement for descriptive statistics and t-tests for each beverage). Insofar as this difference is significant, it supports the extra processing account, but insofar as it is small, it supports the contagion account.

7.2.2 How much does any additive affect naturalness compared to no additive?

To determine the relative size of each of our manipulations, we examined the naturalness of baseline beverages — organic orange juice (*M*=82.66, *SD*=23.44) and organic milk (*M*=83.36, *SD*=22.68). On average adding a small 5% dose compared to the no-intervention baseline reduced naturalness by 21.04 points (e.g., comparing organic milk to organic milk with 5% more fat through 1 process). Tripling that dose reduced naturalness by another 3.69 points (e.g. comparing organic milk with 5% more fat through 1 process to organic milk with 15% more fat through 1 process). Tripling the processing history reduced naturalness by 4.68 points (e.g., comparing organic milk with 15% more fat added through 1 versus 3 processes).

7.3 Discussion

Consistent with both the contagion account and the extra processing account, tripling the dosage of the additive only slightly reduces naturalness, and this effect is relatively small compared to the effect of inserting versus not inserting an additive. Consistent with the extra processing account, adding the same amount of additive with more processes reduces naturalness. However, consistent with the contagion account, the effect of tripling processing history is small.

8 General discussion

In five studies, we examine additivity dominance — an entity with something added is less natural than an entity with the same thing removed. Study 1 demonstrates that adding something is more detrimental to naturalness than removing the same thing, regardless of whether the additive is healthy (e.g., vitamin C) or unhealthy (e.g., sugar). Study 2 extends additivity dominance to the domain of genetic modification, showing that organisms with genes added are perceived as less natural than organisms with genes removed. Study 3 demonstrates that merely framing an entity as a potential additive reduces its naturalness. In Studies 4 and 5, we examine possible mechanisms of additivity dominance.

8.1 Mechanisms of additivity dominance

We do not yet know the mechanisms of additivity dominance, but we examine three accounts. Study 4 shows that the negative connotations of the word "additive" cannot be the sole or even primary explanation of additivity dominance. Using more positive synonyms such as "supplemented" does not increase naturalness. Study 5 offers a test of the validity of both the contagion account and the extra-processing account. Consistent with both accounts, the largest decrease in naturalness occurs for inserting an additive compared to leaving a product unaltered; increasing the dose of the additive has a relatively small effect. Consistent with the extra processing account, increasing the processing history of the additive has a statistically significant impact, reducing naturalness of the final product. However, consistent with the contagion account, the effect of tripling processing history is small. We expect that the contagion and extra processing accounts work in concert. In fact, one possibility is that extra processing reduces naturalness in part because it increases contagion and contact with outside sources. Three processes imply more direct or indirect human contact. One potential direction for future research is exploring the relationships between contagion, processing, and additivity dominance.

We do not yet know exactly why the first effect — the first addition or removal relative to baseline — is so large. One possibility is that an additive product (e.g., organic orange juice with extra pulp) spontaneously brings to mind the product category (e.g., orange juices; see Kahneman & Miller, 1986). In the context of that category, the unaltered organic product (e.g., organic orange juice) represents a state of purity. Any deviation (e.g., by adding or removing orange juice) destroys that purity. This account is consistent with the relatively high naturalness ratings given to baseline products throughout these studies (products that represent a state of purity within the category). However, even if this account is true, it is incomplete. We still do not know why the first addition or removal relative to the baseline product destroys purity. It could be a combination of contagion and processing, or it could involve a yet unidentified process. Contagion predicts almost no effect of tripling the dose or dividing it into three sub parts (three processes). The minimal (though significant) effect of both of these processes suggests a more important role for contagion.

8.2 Relationships to other judgment and decision-making processes

The relationship between the present results and other principles in judgment and decision-making, such as omission bias and status quo bias, is open for future research. Kahneman & Tversky (1982) first observed that people feel more regret when bad outcomes are brought about by actions versus by inactions. Researchers later discovered multiple biases were at work including omission bias — where harms caused by actions are worse than harms caused by inactions — and status quo bias — where people prefer to keep the status quo (Ritov & Baron, 1992; Spranca, Minsk & Baron, 1991). The naturalness bias is closely related to this body of research. Naturalness bias describes a dislike of action (human processing) and desire for status quo (keeping things in nature the same). Indeed, it is possible that perceived naturalness is one mediator for some instances of these effects (e.g., omission bias in vaccination decisions, Asch et al., 1994).

However, we also note that additivity dominance is not easily explained by omission bias or status quo bias. It is true that both accounts predict that additives will reduce naturalness. Additives are generated by human processing and they involve a departure from the status quo (the original state of the product). However, subtractives are also a result of action and involve an equally large departure from the status quo in these studies. Thus, we expect the commission-omission and status quo distinctions are less useful when comparing additives and subtractives, specifically.

8.3 Conclusion

We think examining additivity dominance furthers understanding about the lay definitions of natural and accounts of naturalness judgments. We leave open whether additivity dominance extends to other cultures. We also leave open the possibility that additivity dominance reflects a broader principle that extends beyond naturalness judgments.

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