The impact of dietary supplement form and dosage on perceived efficacy

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Abstract

Purpose – The purpose of this paper is to examine the impact of supplement form and dosage level on consumers' perceptions of dietary supplement efficacy.

Design/methodology/approach – The authors draw upon literature on dietary supplements and accessibility–diagnosticity theory to derive their hypotheses. Hypotheses are tested through two experiments that use a 2 (supplement form: single-ingredient [SI] vs multi-ingredient [MI]) × 2 (dosage level: low vs high) factorial design.

Findings – The findings show that consumers perceive that lower dose MI supplements are more effective than lower dose SI supplements, consistent with a "more is better" heuristic. In contrast, under high doses, the supplement form effect is insignificant; that is, MI and SI supplements are perceived to be comparable in terms of efficacy.

Practical implications – Dietary supplements are not regulated the same way as prescription drugs. Consumers often draw inferences about supplement efficacy based on their perceptions rather than objective evidence. This may leave consumers vulnerable to potentially harmful consequences. This research has implications for designing supplement marketing efforts and public policy, which could help consumers to make informed choices when purchasing dietary supplements.

Originality/value – A growing awareness of the importance of maintaining a healthy lifestyle has motivated consumers of all ages to consider alternative remedies, most notably using dietary supplements. Past research offers little insight into understanding consumer reactions to dietary supplement form such as SI and MI supplements and their dosage levels. The studies reported here address this gap in research. Public policy and marketing implications are also discussed.

Keywords Public policy, Dietary supplements, Perceived efficacy, Supplement marketing

Paper type Research paper

Introduction

A growing awareness of the importance of maintaining a healthy lifestyle (Bolton *et al.*, 2008; Divine and Lepisto, 2005; Rajamma and Pelton, 2010; U.S. Department of Health & Human Services, 2013, 2015) has motivated consumers of all ages to consider complementary and alternative medicines (CAMs), most notably dietary supplements (Royne *et al.*, 2014), one of the fastest-growing categories of CAMs. A majority of American adults (68 per cent) consume dietary supplements (Council for Responsible Nutrition, 2015), with US consumer sales of dietary supplements through retail and direct-to-consumer channels reaching $38.8bn in 2015 (*Nutrition Business Journal*, 2016). In addition, economic conditions have aided supplement sales, as consumers attempt to manage their own health care to avoid expensive doctor visits and prescription medications (Federal Trade Commission, 2010).

Under the Dietary Supplement Health and Education Act (DSHEA) of 1994, a dietary supplement is a product taken by mouth that serves the purpose of supplementing the diet via a "dietary ingredient(s)". Such dietary ingredients include vitamins, minerals, herbs or other botanicals, amino acids and other substances intended to supplement the diet by increasing total dietary intake and concentrates, metabolites, constituents or extracts (US Food and Drug Administration, 2015a, 2015b). Neither regulated as conventional food nor as drugs, Food and Drug Administration (FDA) regulations of dietary supplements constitute a separate category whereby "firms are responsible for evaluating the safety and labeling of their products before marketing to ensure that they meet all the requirements of DSHEA and FDA regulations" (FDA.gov). The Dietary Supplement and Non-prescription Drug Consumer Protection Act of 2016 requires mandatory reporting of serious adverse events associated with supplements and non-prescription drugs. However, the FDA can take action against misrepresented dietary supplement claims or adulterated products only after these supplements have reached the market. Thus, unlike prescription medications, tight regulatory oversight in the dietary supplement category is

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Journal of Consumer Marketing
35/2 (2018) 228–238
 [ISSN 0736-3761]
[DOI 10.1108/JCM-02-2017-2108]

Received 20 February 2017
Revised 29 June 2017
Accepted 7 September 2017

lacking and they are not tested in controlled scientific studies (American Cancer Society, 2013; Crawford and Leventis, 2005).

Despite these regulatory deficiencies (Quinones *et al.*, 2013), consumers hold expectations that they are protected by safety regulations (Mason and Scammon, 2011). This illusion of product safety often results in consumers self-prescribing supplements without expert medical input based on perceived (rather than proven) effectiveness or benefits (American Cancer Society, 2013). This leaves consumers vulnerable to unsafe and inappropriate dosage and combinations of supplement ingredients (Institute of Medicine [IOM], 2008). Furthermore, although supplement deficiencies are possible if consumers do not monitor specific supplement requirements and ingredients carefully, consuming a quantity higher than the recommended dosage may leave consumers vulnerable to overdosing on specific ingredients, especially when they consume a multi-ingredient (MI) supplement or combine multiple single-ingredient (SI) supplements (Lam *et al.*, 2006; Moawad *et al.*, 2006; Mularski *et al.*, 2006). For example, weight-loss supplements often contain multiple ingredients, including caffeine, Hydroxycut, Orlistat (Alli), green coffee bean extract, green tea, conjugated linoleic acid, Glucomannan and other ingredients. Interactions between these ingredients, especially when combined with additional supplements that contain one or more of these ingredients, can have toxic effects on health (Clayton *et al.*, 2017).

Yet, as the IOM (2008) points out, although there is a greater potential for interactions among multiple ingredients, safety and quality standards are only applicable for SI supplements. Moreover, past research that even touches upon supplement form and dosage is survey-based and correlational (Bentley *et al.*, 2006; Koplan *et al.*, 1986; Shapiro *et al.*, 1983). For instance, cross-sectional surveys show that multi-vitamin use varies across demographic groups (Bentley *et al.*, 2006; Koplan *et al.*, 1986). Although such studies may be somewhat meaningful for public policy makers, particularly lacking is an understanding of how consumers form efficacy perceptions (i.e. the perceived effectiveness and usefulness of the dietary supplement) attributed to the joint impact of supplement *form* (i.e. MI vs SI supplements) and supplement *dosage* (i.e. low vs high dosage).

The present research examines this question through two experimental studies that manipulate both *supplement form* (SI vs MI) and supplement *dosage* (low vs high) to examine their joint impact on consumer efficacy perceptions. Specifically, we show that whereas supplement form has a simple "more is better" (MI greater than SI) effect on perceived efficacy under lower dosages, in higher doses, MI and SI supplements are perceived to be comparable in terms of efficacy. Recommendations for public policy are explored along with guidelines for supplement marketing.

Previous research on dietary supplements

Although the literature dealing with consumer perceptions of preventative health-care products, including foods with therapeutic properties, is important (Bhaskaran and Hardley, 2002; Luomala *et al.*, 2015), our primary focus is on the impact of supplement form and dosage on perceived efficacy of dietary supplements. Thus, we limit our discussion to research that specifically deals with dietary supplements, not other health-related foods and products.

In general, most extant research has paid limited attention to the role of supplement form and dosage and their impact on consumer perceptions. Rather, previous consumer research on dietary supplements primarily examines consumer reactions to dietary supplement marketing, including direct-to-consumer advertising (DTCA), unsubstantiated dietary supplement claims, product warnings and disclaimers (Bone and France, 2009; Crawford and Leventis, 2005; Eggers and Fischhoff, 2004; France and Bone, 2005; Mason, 1998; Mason *et al.*, 2007; Mason and Scammon, 2011; Royne *et al.*, 2014; Vladeck, 2000). One such effort finds that government-mandated disclaimers do not impact consumers' beliefs about the efficacy or safety of dietary supplements, and that heavy users respond differently to disclaimers than light supplement users (Mason *et al.*, 2007). The FDA has authorized a number of initiatives designed to improve product labeling so that consumers can make "smarter" decisions about supplements. In response, some research has looked at the information environment within the dietary supplement industry. For example, France and Bone (2005) found that consumers do not distinguish between different types of claims (e.g. structure function claims vs disease claims) on supplement labels, and that general beliefs about the supplement industry impact product-specific efficacy judgments. Moreover, Mason and Scammon (2011) showed that consumers often express confusion about the actual meaning of supplement claims and largely found them ambiguous and vague.

Another stream of research compares the relative impact of dietary supplements versus prescription drugs on consumers' perceptions of a healthy lifestyle. Compared to dietary supplements, drugs reduce perceptions of health, diminish the importance of healthy lifestyle practices and lead to lower motivation to engage in health-protective behaviors (Bolton *et al.*, 2008). Subsequently, Royne *et al.* (2014) examined the impact of health-consciousness on consumer attitudes and perceptions of supplement benefits and risks compared to prescription drug counterparts. In addition, research has explored the relationship of demographic factors (e.g. education, gender and age) on beliefs about and intent to use supplements (Chandra *et al.*, 2005; Gordon and Schaffer, 2005; Kimmons *et al.*, 2006). In summary, extant research on supplement usage offers limited insight into the role of supplement form and dosage and their impact on consumer perceptions of efficacy. And, to the best of our knowledge, no experimental studies have examined the causal link between supplement form, dosage level and perceived efficacy.

The role of supplement form and dosage in perceived efficacy

Although literature on supplement form and dosage is scant, there is limited research which suggests that supplement consumption may be influenced by a "more is better" heuristic which in turn can lead to harmful consumer behaviors such as megadosing of supplements (Maughan *et al.*, 2004). Indeed, within a broader consumer decision-making context, a "more is better" heuristic is commonly encountered (Peters *et al.*, 2013).

For example, research shows that consumers desire more information while making decisions irrespective of the relevance of that information (Keller and Staelin, 1987; Redelmeier *et al.*, 2001) due to increased perceived control and an inherent preference for more choices (Bandura, 1986; Leotti and Delgado, 2011). Underlying the "more is better" heuristic is the belief that more will lead to positive additive and synergistic effects (Peters *et al.*, 2013). However, in addition to a consumer bias toward higher supplement dosages as noted in the literature (Maughan *et al.*, 2004), a "more is better" heuristic can also manifest through greater consumer preference and evaluation for supplements with multiple (vs single) ingredients. In particular, given the backdrop of incomplete and vague information about supplements which can lead to confusion (Mason and Scammon, 2011), consumers are more likely to process information through the peripheral route where they make inferences based on simple cues (Marshall *et al.*, 2002; Petty and Cacioppo, 1984). This argument is based on research by Petty and Cacioppo (1984, 1986) which demonstrates that when consumers lack the ability to think about a message (e.g. when they have incomplete information or knowledge), they form favorable attitudes based on simple acceptance cues such as number of arguments (vs quality of arguments) in a message. Likewise, the number of ingredients in a supplement may behave as a peripheral cue (similar to number of arguments in a message), which in turn may signal that the MI (vs SI) supplement was somehow better and, thus, more efficacious based on the "more is better" heuristic.

But how do supplement dosage and form interact to influence supplement efficacy judgments? We suggest that the accessibility–diagnosticity framework (Feldman and Lynch, 1988) may offer insights into understanding how consumers form perceptions about the efficacy associated with SI and MI supplements with varying dosage levels (Catlin *et al.*, 2015). Applied across social science fields (Ahluwalia and Gürhan-Canli, 2000; Catlin *et al.*, 2015; Herr *et al.*, 1991; Menon *et al.*, 1995), the accessibility–diagnosticity framework posits that the probability that information will be used in forming judgments is dependent on the degree to which the information is both accessible and diagnostic. In particular, the likelihood that an information cue will be used in forming consumer judgments depends on the extent to which the cue is accessible in memory, the extent to which the cue is perceived as diagnostic and an inverse function of the extent to which other alternative cues are accessible in memory and/or perceived as diagnostic (Feldman and Lynch, 1988). Based on the accessibility–diagnosticity model, we propose that at low dosage levels, supplement dosage is perceived as non-diagnostic (due to the more dosage is better heuristic). In turn, this enhances the likelihood that the supplement form cue is diagnostic and used as input in the formation of consumers' perceived efficacy judgments. This will lead to greater perceived efficacy of MI compared to SI supplements based on the more (ingredients) is better heuristic. However, at high dosage levels, dosage is perceived as a diagnostic cue. As the extent to which a cue will be used in consumer judgments is an inverse function of the extent to which other alternative cues are perceived as diagnostic, this reduces the likelihood that the supplement form cue will be used as an input when consumers form perceived efficacy judgments. Thus, we expect that at high dosage levels, there will be no difference between perceived efficacy of MI and SI supplements.

To summarize, we argue that perceptions about the efficacy of SI and MI supplements vary across dosage levels, such that:

H1. Supplement form and dosage interactively impact perceived efficacy.

H1a. At low dosage levels when the supplement form cue is diagnostic, MI supplements are perceived to be more effective than SI supplements.

H1b. At high dosage levels, the difference between the perceived efficacy of SI versus MI supplements is insignificant.

We describe two studies that manipulate supplement form and dosage levels to test the aforementioned hypotheses. The focal dependent variable in both studies is perceived efficacy. In addition, we explore the "more is better" heuristic as an underlying process in Study 2.

Study 1

Methodology

Subjects and procedure

Undergraduate students enrolled in business courses at a large state-supported institution completed Study 1 (S1) for course credit (N = 99, 62 per cent female, average/median age = 24.2/22).

Participants reflect Western US ethnic patterns: White/Caucasian (29 per cent), Asian/Asian American (34 per cent), Hispanic/Latino (27 per cent), Black/African American (2 per cent), Mid-Eastern (2 per cent) and Other (6 per cent). The computer-operated sessions conducted in a small research laboratory (maximum number of participants per session = 8) randomly assigned participants to experimental treatments (administrator was blind to assignments).

Respondents were first informed that the study was about "health-related product choices and behaviors." Brief instructions included a definition of dietary supplements to familiarize participants with the meaning of the term used frequently in the study:

> A dietary supplement is a product intended for ingestion that contains a "dietary ingredient" intended to add further nutritional value to (to supplement) the diet. A "dietary ingredient" may be one, or any combination, of the following: a vitamin, a mineral, an herb, or an amino acid.

After reading general instructions and the above dietary supplement definition, participants viewed a print advertisement proof and Supplement Facts label for an unknown supplement (exposure timed for a minimum of 15 s). After the viewing task, respondents completed the remaining dependent measures (self-paced).

Design and manipulations

S1 uses a two-factor (*supplement form* [MI vs SI supplement] and *dosage level* [low vs high]) between-subjects design.

Supplement form. The supplement form (SI and MI) is manipulated within an advertisement proof and Supplement Facts for a dietary supplement that features a hypothetical

brand, Nature's Gift, classified as a memory enhancer, chosen for its relevance to the student participants (Higbee, 2004). The brand name is kept purposefully general so as not to convey any particular goal or use of the pictured dietary supplement, and to not convey specific product attributes.

The SI advertisements state that "Nature's Gift is a dietary supplement that contains Vinpocetine," and the MI ads indicate that the product is a dietary supplement that contains "Vinpocetine, Huperzine A, and L-Carnitine" (ingredients associated with memory). Ingredients for each dietary supplement form are then repeated on the supplement bottle pictured in the ad, along with the number of capsules ("90 capsules"). The headline is positioned beneath the brand name: *The Way to Improved Memory*. As typical for print ads, four generic product claims were included:

1 contains only high-quality ingredients;
2 potency guaranteed;
3 manufactured under strict quality control standards; and
4 free of contaminants.

The ads are identical in terms of size, verbal and image positioning, coloring, format, typeface, etc. (See Appendix 1 for the Supplement Facts stimuli; also see Appendix 2 for pretest details.)

Supplement dosage. The second two-level factor in S1, *supplement dosage*, is manipulated via the supplement ingredient milligrams listed in the associated Supplement Facts (Appendix 1). Low versus high dosage level is manipulated via the number of milligrams (mg) per supplement capsule, judged to represent "low" versus "high" dosage levels in a pretest (see Appendix 2 for pretest details). For example, the low dosage level SI/MI supplement contained 150 mg of the primary ingredient and the high dosage level SI/MI supplement contained 1,200 mg of the primary ingredient.

Dependent measures

Participants answered a series of questions designed to capture the key dependent constructs. All measures in both studies reported here are assessed via nine-point scales, unless otherwise indicated. Our focus is on *perceived efficacy*, which is measured via two bipolar scales (Batra and Ahtola, 1990; not effective/very effective, not useful/very useful; Spearman Brown Reliability Coefficient [SBRC] = 0.91).

To assess ad stimuli comparability, participants evaluated their overall impressions of the advertisement via bipolar scales (i.e. *Aad*; unfavorable/favorable, bad/good, negative/positive, $\alpha = 0.94$), along with other ad-based judgments (low quality/high quality, not creative/very creative, not informative/very informative, hard to understand/easy to understand). Involvement and interest in the study are averaged for a reliable task involvement scale (not at all involved/very involved, not at all interested/very interested; SBRC = 0.83). Prior knowledge of memory supplements and supplements in general is measured via two questions with "not at all knowledgeable" and "very knowledgeable" end points ("How knowledgeable are you about dietary supplements in general (designed to enhance memory)?"; SBRC = 0.73).

Consistent with the initial study description and cover story, respondents also answered questions about their own health. Two items (strongly disagree/strongly agree) capture personal health beliefs ("Exercise is essential in maintaining a healthy lifestyle," "Eating right is essential in maintaining a healthy lifestyle"; SBRC = 0.86; cf. Bolton *et al.*, 2008). In addition, participants reported how often they take dietary supplements, exercise and eat healthy versus unhealthy foods and beverages (end points from "never" to "very often"). Finally, participants were asked to record their thoughts about the purpose of the study (analyses of these verbatims find no evidence that respondents were aware of the study purpose) and to provide basic demographic information (gender, age and ethnicity).

Results – Study 1

Ad judgments and covariates

Results indicate no significant main or interactive effects of supplement form or dosage on the ad judgment scales (informativeness [$p > 0.43$], ease of understanding [$p > 0.39$], quality [$p > 0.16$], creative [$p > 0.15$]), thereby confirming that the ads were comparable. The four treatment groups are comparable in terms of task involvement ($p > 0.86$), supplement usage ($p > 0.77$), health behaviors (all $p > 0.46$), gender ($p > 0.86$) and age ($p > 0.31$). Based on past evidence that knowledge impacts product choice and information processing (Brucks, 1985; Johnson and Russo, 1984; Rao and Monroe, 1988), and related evidence that expertise impacts perceptions about over-the-counter drugs (Catlin *et al.*, 2015), supplement knowledge is included as a covariate in all hypothesis tests.

Hypothesis tests

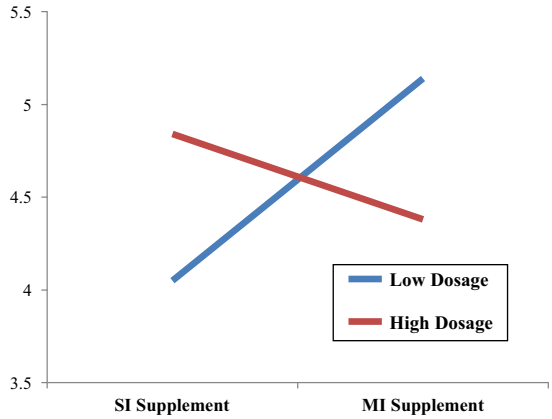
S1 manipulates supplement form and dosage level to explore their impact on perceived efficacy. The hypotheses are tested via a 2 (supplement form) × 2 (dosage level) analysis of covariance (ANCOVA), controlling for knowledge. As predicted (*H1*), supplement form interacts with dosage to impact perceived efficacy, $F(1, 94) = 4.68$, partial $\eta^2 = 0.05$, observed power = 0.57, $p = 0.03$[1]. Planned linear pairwise comparisons, $F(1, 94) = 4.40$, $p < 0.05$, reveal that participants perceive that the low-dose MI supplement ($M = 5.14$) is more effective than the low-dose SI supplement ($M = 4.05$; *H1a*). In contrast, comparisons show that high doses of the SI supplement ($M = 4.84$) are comparable ($p > 0.35$) to high doses of the MI supplement ($M = 4.38$; *H1b*) (Figure 1 and Table I).

Study 2

Study 2 (S2) design replicates S1 with the following revisions and additions:

- To conform to common supplement label standards, the Supplement Facts include per cent daily value information.
- The memory supplement ingredients are revised. The primary supplement ingredient was changed to Citicoline, a supplement associated with memory benefits, because the ingredient used in S1 (Vinpocetine) was recently tentatively redefined by the FDA as not being a "dietary supplement." The second ingredient in the MI product used in S1 (l-Carnitine) was replaced based on its association with weight building. Phosphatidylserine is the second ingredient in S2. The third ingredient in the MI product remains the same as that used in S1, Huperzine A.

Figure 1 The interaction of supplement form and dosage (S1): perceived efficacy



- The low and high dosage amounts are revised for S2 based on recommended dosage levels. For a stricter control of serving size and suggested dosage, the Supplement Facts' Directions and Serving Size information are also revised.

Importantly, S2 also attempts to understand the underlying processes driving the findings in S1 that consumers perceive MI supplements as more effective than SI supplements under low dosage levels. Specifically, we suggest that this effect may be driven by a "more is better" heuristic which may increase diagnosticity of the supplement form cue when combined with limited diagnosticity of the low dosage cue. Thus, we hypothesize that:

H2. Under low dosage, consumers' beliefs that the supplement is effective because it has more ingredients mediate the effect of supplement form on perceived efficacy.

Methodology

Subjects and procedure

Undergraduate students (from the same general population as S1) enrolled in business courses at a large state-supported institution completed S2 for course credit ($N = 176$, 51 per cent male, average/median age = 23.1/22). Participants reflect Western US ethnic patterns: White/Caucasian (24 per cent), Asian/Asian American (30 per cent), Hispanic/Latino (36 per cent), Black/African American (2.3 per cent), Mid-Eastern (2.3 per cent and Other (5.4 per cent). The procedure for stimulus exposure and data collection replicates that used in S1.

Design and manipulations

As per S1, S2 uses a two-factor (*supplement form* [MI vs SI] and *dosage level* [low vs high]) between-subjects design with random assignment to treatments.

Supplement form. *Supplement form* is manipulated via an ad and Supplement Facts, as in S1. The SI advertisements state that "Nature's Gift is a dietary supplement that contains Citicoline," and the MI ads indicate that the product is a dietary supplement that contains "Citicoline, Phosphatidylserine, and Huperzine A." All other ad elements remain the same as those used in S1.

Supplement dosage. The second two-level factor, *supplement dosage*, is manipulated via dosage level in the associated Supplement Facts. The milligrams associated with each supplement ingredient are based on the low and high recommended dosage levels. For example, the recommended dosage for Citicoline ranges from 500 to 2,000 mg. Thus, the low-dosage-level SI/MI supplement contains 500 mg of the primary ingredient and the high-dosage-level SI/MI supplement contains 2,000 mg of Citicoline. Directions state "Take 1 capsule 3 times a day," and the serving size is noted as "1 capsule" (Appendix 3).

Dependent measures

As in the previous study, the primary focus here is on *perceived efficacy*, assessed via two bipolar scales [SBRC] = 0.86). (For details on measures, see S1.) In addition, to tap into the "more is better" heuristic, participants also indicated their level of agreement (nine-point strongly disagree/strongly agree scale) with the statement, "The supplement is effective because it has more ingredients." To confirm stimuli equivalence, participants evaluated their overall impressions of the advertisement (i.e. *Aad*, $\alpha = 0.93$), along with other ad-based judgments similar to those used in S1.

Knowledge with dietary supplements in general, supplements designed to enhance memory and recommended dosages of memory-enhancing supplements are each assessed via two bipolar scales ("not at all knowledgeable/very knowledgeable," "I know nothing/I know a lot"; SBRC = 0.97, 0.99 and 0.98, respectively).

Perceived dosage is measured via two bipolar scales ("low/high quantity," "low/high dosage"; SBRC = 0.88). The same potential covariates and cover story items from S1 are included (e.g. health behaviors and task involvement [SBRC = 0.90]).

Analyses of the study purpose verbatims find no evidence that S2 participants were aware of the study purpose.

Results – Study 2

Manipulation checks, ad judgments and covariates

Perceptions of dosage quantity behave as expected: The high-dosage supplement capsules were judged to contain a higher dosage than the low-dosage supplements ($M = 6.71$ vs 5.78), $F(1, 169) = 19.67$, partial $\eta^2 = 0.10$, observed power = 0.99, $p < 0.001$. Results indicate no significant main or interactive effects of supplement form or dosage on the ad judgment scales (informativeness [$p > 0.35$], ease of understanding

Table I Summary of treatment statistics: means and standard errors

Dependent variable: perceived efficacy	SI – low dosage	MI – low dosage	SI – high dosage	MI – high dosage
Study 1	4.052[a] (0.36)	5.140[a] (0.37)	4.835 (0.33)	4.381 (0.36)
Study 2	4.334[a] (0.27)	5.142[a] (0.29)	4.972 (0.29)	4.681 (0.27)

Note: [a]Means differ ($p < 0.05$)

[$p > 0.25$], quality [$p > 0.65$], professionalism [$p > 0.13$], *Aad* [$p > 0.40$]), thereby confirming that the ads are comparable. The four treatment groups are comparable in terms of task involvement ($p > 0.78$), supplement usage ($p > 0.48$), health behaviors (all $p > 0.30$), gender ($p > 0.61$) and age ($p > 0.78$). Knowledge of supplements, memory supplements and dosage are controlled via covariates in all hypothesis tests.

Hypothesis tests: H1, H1a, H1b

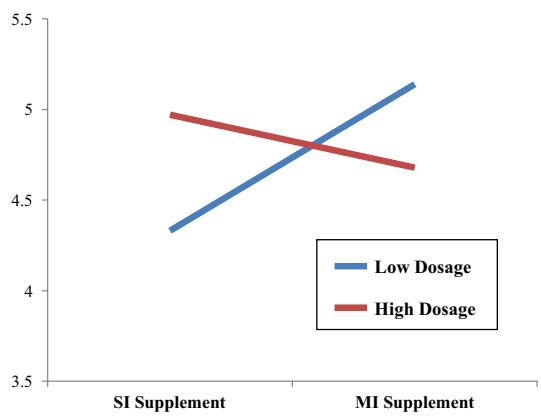
H1 is tested via a 2 (supplement form) × 2 (dosage level) ANCOVA with the three knowledge covariates. As predicted (*H1*) and consistent with previous findings, supplement form interacts with dosage to impact perceived efficacy, $F(1, 169) = 3.96$, partial $\eta^2 = 0.03$, observed power = 0.51, $p < 0.05$[2]. Predicted linear pairwise comparisons, $F(1, 169) = 4.40$, $p < 0.04$, reveal that participants perceive that the low-dose MI supplement ($M = 5.14$) is more effective than the low-dose SI supplement ($M = 4.33$; *H1a*). In contrast, planned comparisons show that high doses of the SI supplement ($M = 4.97$) are not significantly different ($p > 0.46$) than high doses of the MI supplement ($M = 4.68$; *H1b*) (Figure 2 and Table I).

Mediation tests: H2

The mediating impact of beliefs about the number of ingredients (M) on the relationship between supplement form (X) and perceived efficacy (Y) under low dosage levels (*H2*) with three knowledge variables as covariates is tested via Hayes' (2013) PROCESS model (Model 4 with 10,000 samples; see Appendix 4 for Hayes PROCESS output):

- The indirect paths show that the effect of supplement form on beliefs about more ingredients is significant ($b = 1.18$, $t = 2.83$, $p < 0.01$), and beliefs about more ingredients impact perceived efficacy ($b = 0.23$, $t = 2.38$, $p < 0.01$).
- The direct effect of supplement form on perceived efficacy controlling for the beliefs mediator is not significant ($b = 0.45$, $t = 1.14$, $p > 0.25$).
- The indirect effect of supplement form on efficacy through beliefs about more ingredients was tested using a bootstrap estimation approach: effect = 0.28, SE = 0.14, 95 per cent CI range = 0.07-0.642. Notably, zero is not included in this range, which supports the mediation hypothesis (*H2*) (Hayes, 2013). Thus, under low supplement dosage levels, beliefs that the supplement is more effective because it has more ingredients mediate the impact of supplement form on perceived efficacy.

Figure 2 The interaction of supplement form and dosage (S2): perceived efficacy



General discussion

Theoretical contributions and implications

This research examines consumers' perceptions of efficacy associated with supplement form and dosage via an experimental design. Given the vague and ambiguous regulatory environment (Crawford and Leventis, 2005; Mason and Scammon, 2011), consumers face informational deficits when making supplement choices, thereby limiting their ability to make optimal decisions. Thus, consumers may be vulnerable to unethical behavior on the part of supplement manufacturers (Bateman *et al.*, 2013). A better understanding of how consumers develop supplement efficacy judgments is crucial from a public policy standpoint which aims to design regulations and remedies that reduce the potential of maladaptive usage of supplements.

In contrast to past research that primarily focuses on consumers' reactions and interpretations of supplement label claims, product warnings, disclaimers and DTCA (Bone and France, 2009), our focus is on consumers' perceptions of efficacy as a result of the interplay between supplement form (MI vs SI) and dosage level (high vs low). To the best of our knowledge, this is the first empirical effort to assess the interaction between supplement form and dosage level and its impact on consumers' efficacy perceptions.

Specifically, past research suggests that megadosing of dietary supplements is common due to a "more is better" heuristic. However, a "more is better" heuristic can also manifest through greater preference for multiple (vs single) ingredient supplements, especially when consumers seek to simplify their consumption decisions (Petty and Cacioppo, 1984) within the context of incomplete information about dietary supplements. Based on this work and drawing upon an accessibility–diagnosticity framework, we suggest that at low dosage levels, the supplement dosage cue will have limited diagnosticity. In this case, the supplement form cue will be considered as a diagnostic cue in perceived efficacy judgments (due to "more is better" heuristic as a result of consumers' tendency to simplify choice decisions). Thus, we predict that at low supplement dosage levels, MI supplements are perceived as more efficacious than SI supplements. However, at high dosage levels, the diagnosticity of the dosage cue increases, which in turn reduces the diagnosticity of the supplement form cue. In this case, we predict that there is no difference between MI and SI supplements. Results from two studies that manipulate both supplement form and dosage via an advertisement show that MI supplements are indeed perceived to be more efficacious than SI supplements at low (vs high) doses. Moreover, our findings also show that at low doses, the perceived efficacy of MI (versus SI) supplement is driven by the belief that the supplement is effective because it has more ingredients, which is reflective of the "more is better" heuristic and the increased diagnosticity of the supplement form cue.

From a public policy and consumer well-being perspective, our data show that consumers are willing to make efficacy judgments based on limited information. Without evidence that the advertised MI supplement was tested under controlled settings or that the supplement has been shown to enhance memory in clinical trials, participants still found the MI supplement to be more effective than SI supplement at lower doses. Unsubstantiated benefit claims along with insufficient acknowledgment of potential side effects and risks often found in dietary supplement promotions represent a public health threat (Crawford and Leventis, 2005). Indeed, given that there is a greater likelihood of interactions between multiple ingredients (IOM, 2008), our findings suggest the importance of additional regulation guidelines for packaging and promotional messages regarding individual ingredient benefits in the MI supplement category (Temple, 2010) even when they are taken at low dosage levels.

Moreover, if high dosage overpowers the diagnosticity of supplement form cues, consumers may neglect to consider potential interactions among supplement ingredients and/or other medications. Marketers and policy makers must work to inhibit such behaviors, as maladaptive usage of supplements at high dosage levels may result in irreversible, perhaps life-threatening, harm.

From a managerial perspective, our findings suggest that MI supplement marketers can promote that multiple ingredients provide more benefits especially under low dosage levels. Our results demonstrate that consumers perceived multiple ingredients as more effective at lower dosage levels, suggesting that a "more is better" heuristic is applicable. However, SI supplement brands must focus on the power or dosage of the specific single ingredient while trying to motivate consumers to understand that one ingredient is enough to achieve efficacy. In addition, marketers of high-dosage MI supplements may also design promotional tools that work to overcome the limited diagnosticity of the supplement form cue evidenced here.

Future research directions

The most obvious avenue of future study is to determine if the effects reported here are robust across other types of supplements, samples and settings. The memory enhancer used in our research was chosen for its appropriateness for the sample. Many consumers, including the elderly, use supplements as alternatives to traditional medicine for prevention and treatment purposes (e.g. various supplement cocktails designed to treat cold symptoms, calcium to prevent/treat osteoporosis). Future research may explore the impact of such individual differences on perceived efficacy associated with supplements, especially in field settings outside the laboratory. For example, consumers frequently encounter in-store promotions of dietary supplements in grocery stores. Field experiments may offer insights into the extent to which consumers rely on marketing promotional tactics versus other more objective sources.

Moreover, although the focus of our research is on the joint impact of supplement form and dosage on perceived efficacy, it may also be argued that more ingredients lowered perceived risk, which in turn may have increased perceived efficacy (Alhakami and Slovic, 1994). Future research should explore the role of perceived risk.

The MI > SI under lower dosage effect replicated across our studies reflects a "more is better" heuristic, often also termed a naïve belief or lay theory (Furnham, 1988; Hughner and Kleine, 2008). Future studies should explore the relevance of other health-related heuristics and naive/lay beliefs in understanding dietary supplement usage and perceptions (e.g. "no-pain, no- gain"; Kramer *et al.*, 2012).

S1 included dosage levels purposefully manipulated such that the total recommended milligrams were equivalent for the primary ingredient in the SI versus MI supplements. S2 was careful to assign milligrams based on established recommended dosages. Although we successfully created "low" versus "high" dosage, levels study of alternative forms of dosage levels is warranted: for example, test higher total milligrams or total number of "pills" or manipulate individual ingredient milligrams. The ad stimuli did not include any sort of disclaimer or warning information (Mason *et al.*, 2007). Additional study may examine whether such information in a supplement ad (or packaging) is effective at educating the public about the benefits and potential side effects associated with various supplement products.

The promotional stimuli used here were framed in a manner that may have induced a promotion regulatory focus, i.e. the ads conveyed product benefits (gains). Past research suggests that certain products can temporarily trigger a consumer's regulatory focus (vs a prevention focus) and that health-related messages designed to fit this regulatory focus are more persuasive than those that do not (Borges and Gomez, 2015). Future studies may manipulate regulatory focus or other types of message framing.

Notes

1 Results and conclusions are unchanged when the knowledge covariate, effect $F(1, 94) = 5.29$, $p < 0.05$, is excluded from analyses: The supplement form × dosage interaction effect is significant ($p < 0.05$).

2 Results and conclusions are unchanged when the three covariates, knowledge of supplements, $F(1, 169) = 1.20$, ns; memory supplements, $F(1, 169) = 2.07$, ns; and supplement dosage, $F(1, 169) < 1.0$, ns, are excluded from analyses: The supplement form × dosage interaction effect is significant ($p < 0.05$).

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Appendix 1. Supplement facts – Study 1

SI / High (Low) Dosage

Directions: Take 1-3 times a day.	
Supplement Facts Serving Size: 1-3 Capsules	
	Amount per capsule
Vinpocetine	1,200 (150)mg
Other ingredients: Capsule (100% vegetarian). No fillers, binders, common allergens.	
Discussion: This product is derived from special high-quality grade Vinpocetine.	

MI / High (Low) Dosage

Directions: Take 1-3 times a day.	
Supplement Facts Serving Size: 1-3 Capsules	
	Amount per capsule
Vinpocetine	1,200 (150)mg
HuperzineA	100 (10)mg
L-Carnitine	100 (10)mg
Other ingredients: Capsule (100% vegetarian). No fillers, binders, common allergens.	
Discussion: This product is derived from special high-quality grade Vinpocetine, Huperzine A, and L-Carnitine.	

Appendix 2. Pretest results

Undergraduate students from the same general population as S1 and S2 completed one of two pretest studies for course credit to assess reactions to the supplement form and dosage stimuli, respectively (P1: N = 24, 65 per cent male, average/median age = 26.1/23, and P2: N = 30, 52 per cent male, average/median age = 25/22.5). As in the main studies, participants in both pretests were told they were completing a study about health products and behaviors. As in S1 and S2, all pretest tasks are completed via online surveys built within the Qualtrics platform, and participants are randomly assigned to treatments. After general instructions and reviewing the dietary supplement definition (see S1 and S2 for details), participants viewed either the supplement ad (P1) or the Supplement Facts (P2) stimuli used in S1, followed by a few self-paced questions.

The first pretest (P1) uses a single-factor (*supplement form*: MI vs SI) between-subjects design. As desired, those who viewed the MI supplement ad agreed more strongly that the advertised dietary supplement product contained more than one supplement ingredient than the product featured in the SI supplement ad (M_{MI} = 7.55 vs M_{SI} = 2.54), $F(1, 22) = 31.02$, partial $\eta^2 = 0.59$, observed power = 1.0, $p < 0.001$. In addition, those who viewed the SI supplement ad agreed more strongly that the advertised dietary supplement contained a single supplement ingredient (M_{SI} = 7.54 vs M_{SI} = 2.82), $F(1, 22) = 23.77$, partial $\eta^2 = 0.52$, observed power > 0.99, $p < 0.001$, supporting that the supplement form manipulation behaved as intended.

P2 uses a single-factor (*dosage*: low vs high) between-subjects design. For the bipolar (low/high) dosage scale, the high-dosage supplement was rated as being higher dosage than the low-dosage supplement (M = 7.59 vs 5.38), $F(1, 28) = 10.98$, partial $\eta^2 = 0.28$, observed power = 0.89, $p = 0.003$. All respondents also correctly identified how many milligrams of the Vinpocetine supplement ingredient the product contained. In summary, the findings from two pretests support that the supplement form and dosage manipulations behaved as intended.

Appendix 3. Supplement facts – Study 2

SI / High (Low) Dosage

Directions: Take 1 capsule 3 times a day.		
Supplement Facts Serving Size: 1 Capsule		
	Amountper capsule	**% Daily Value**
Citicoline	2000 (500)mg	*
* Daily Value not established.		
Other ingredients: Capsule (100% vegetarian). No fillers, binders, common allergens.		
Discussion: This product is derived from special high-quality grade Citicoline.		

MI / High (Low) Dosage

Directions: Take 1 capsule 3 times a day.		
Supplement Facts Serving Size: 1 Capsule		
	Amountper capsule	**% Daily Value**
Citicoline	2000 (500)mg	*
Phosphatidylserine	200 (50)mg	*
HuperzineA	200 (50)mcg	*
* Daily Value not established.		
Other ingredients: Capsule (100% vegetarian). No fillers, binders, common allergens.		
Discussion: This product is derived from special high-quality grade Citicoline, Phosphatidylserine, and Huperzine A.		

Appendix 4

Output for Mediation Tests (H2)

[H2] Supplement form (X) → Beliefs about # ingredients (M) → Perceived efficacy (Y)

Hayes PROCESS Output

```
Run MATRIX procedure:

************** PROCESS Procedure for SPSS Release 2.16.1 *****************

          Written by Andrew F.Hayes,Ph.D.          www.afhayes.com
    Documentation available in Hayes (2013). www.guilford.com/p/hayes3

**************************************************************************
Model = 4
    Y = Effi2A (*Efficacy)
    X = FormN (*Supplement Form)
    M = Reas2 (*consumers' beliefs that the supplement is effective because
it has more ingredients)

Statistical Controls:
CONTROL=BKnow     MKnow    DKnow (Knowledge covariates)

Sample size90

**************************************************************************
Outcome: Reas2

Model Summary
          R        R-sq         MSE           F         df1         df2           p
      .3968       .1574      3.9095      3.9703      4.0000     85.0000       .0053

Model
              coeff         se          t          p       LLCI       ULCI
constant     1.4255      .5260     2.7099      .0081      .3796     2.4714
FormN        1.1838      .4176     2.8348      .0057      .3535     2.0141
BKnow         .0643      .1233      .5213      .6035     -.1808      .3093
MKnow         .2494      .1518     1.6435      .1040     -.0523      .5511
DKnow        -.0100      .1255     -.0795      .9368     -.2595      .2396

**************************************************************************
Outcome: Effi2A

Model Summary
          R        R-sq         MSE           F         df1         df2           p
      .3519       .1238      3.1764      2.3742      5.0000     84.0000       .0458

Model
              coeff         se          t          p       LLCI       ULCI
constant     3.7667      .4942     7.6219      .0000     2.7840     4.7495
Reas2         .2326      .0978     2.3790      .0196      .0382      .4270
FormN         .4487      .3938     1.1394      .2578     -.3344     1.2318
BKnow        -.0762      .1113     -.6845      .4955     -.2975      .1451
MKnow         .0459      .1389      .3302      .7421     -.2304      .3222
DKnow         .0713      .1131      .6300      .5304     -.1537      .2963
************************ TOTAL EFFECT MODEL ****************************
Outcome: Effi2A

Model Summary
          R        R-sq         MSE           F         df1         df2           p
      .2545       .0648      3.3505      1.4721      4.0000     85.0000       .2178

Model
              coeff         se          t          p       LLCI       ULCI
constant     4.0983      .4870     8.4160      .0000     3.1301     5.0665
FormN         .7240      .3866     1.8729      .0645     -.0446     1.4927
BKnow        -.0612      .1141     -.5366      .5929     -.2881      .1657
MKnow         .1039      .1405      .7395      .4616     -.1754      .3832
DKnow         .0690      .1162      .5935      .5544     -.1621      .3000

***************** TOTAL, DIRECT, AND INDIRECT EFFECTS ********************

Total effect of X on Y
     Effect         SE          t          p       LLCI       ULCI
      .7240      .3866     1.8729      .0645     -.0446     1.4927

Directeffect  of X on Y
     Effect         SE          t          p       LLCI       ULCI
      .4487      .3938     1.1394      .2578     -.3344     1.2318

Indirect effect of X on Y
         Effect    Boot SE   BootLLCI   BootULCI
Reas2     .2753      .1408      .0686      .6422

Partially standardized indirect effect of X on Y
         Effect    Boot SE   BootLLCI   BootULCI
Reas2     .1483      .0751      .0331      .3320

Completely standardized indirect effect of X on Y
         Effect    Boot SE   BootLLCI   BootULCI
Reas2     .0757      .0375      .0188      .1705

Ratio of indirect to total effect of X on Y
         Effect    BootSE    BootLLCI   BootULCI
Reas2     .3803   192.7790      .0157     3.2498

Ratio of indirect to direct effect of X on Y
         Effect    BootSE    BootLLCI   BootULCI
Reas2     .6136    32.4590     -.8198    33.1320

Normal theory tests for indirect effect
     Effect         se          Z          p
      .2753      .1565     1.7592      .0785

******************** ANALYSIS NOTES AND WARNINGS ************************

Number of bootstrap samples for bias corrected bootstrap confidence
intervals:
    10000

Level of confidence for all confidence intervals in output:
    95.00

------ END MATRIX -----
```

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