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Lay biology in health: How adults conceptualize the benefits of exercise

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Abstract

We present an approach to health interventions based on the insight that throughout life, individuals construct intuitive theories to predict, explain, and determine how to act on the world. We propose that an intuitive theory-based approach may be useful for teaching adults about the body's biochemical response to exercise. The first step in using this approach is to document the theories that a target population brings to bear on a health domain. We therefore present what is to our knowledge the first investigation of adults' reasoning about exercise. Specifically, we explore how adults explain why exercise confers various benefits, how plausible adults find the physical, emotional, and cognitive benefits of exercise, and how contingent on weight loss adults believe such benefits to be. These findings lay the groundwork for constructing an intervention to motivate adults to exercise more.

Keywords: health, intuitive theories, folkbiology

Introduction

Throughout life, individuals construct and use coherent belief systems, or intuitive theories, to predict, explain, and determine how to act upon the world (Carey, 1987, 2009; Murphy & Medin, 1985; Gopnik & Wellman, 1994; Au, Romo, & DeWitt, 1999; R. Gelman, Brennenman, Macdonald, & Roman, 2009; S. Gelman, 2003). This insight has so far remained largely untapped, however, as a resource for health interventions.

We present an approach to health interventions that leverages participants' intuitive theories, builds on them when appropriate, and corrects misconceptions that would interfere with understanding the health message when necessary. This approach goes beyond most knowledge-based interventions that provide facts, "do's and don'ts," and admonitions without a coherent explanatory framework (see Au, Romo, & DeWitt, 1999). The intuitive theory based approach takes stock of participants' existing theories in the relevant domain, considers the specific nature of the health message, and determines what conceptual prerequisites need to be in place for participants to understand the message thoroughly, apply it flexibly, and believe it with conviction. The present work takes stock of participants' existing theories regarding exercise.

Gripshover and Markman (in press) used this intuitive theory based approach to teach young children that foods have different nutritional profiles—no one food provides all the nutrients the body needs—and therefore we need a variety of healthy foods. This explanation relies on several concepts, some readily understandable and others opaque. Preschoolers may find invisible, discrete, heterogeneous nutrients inside homogeneous-looking food puzzling because they expect

substances to be continuous (Au, 1994). Because preschoolers understand solutions (Au, Sidle, & Rollins, 1993; Rosen & Rozin, 1993), nutrients were explained by analogy to sugar dissolving in water. Nutrient extraction during digestion was explained in mechanical (not biochemical) terms: food enters the body, the stomach breaks it into smaller pieces, extracts the nutrients, and blood carries them throughout the body. This built on children's emerging mechanical understanding of digestion in which food enters and eventually exits the body, but little is known about the intermediate processes of digestion (Teixeira, 2000; Rowlands, 2004). Labels were used to unite perceptually distinct foods into food-group categories and convince children that they share important internal properties (S. Gelman & Markman, 1986). Finally, while children believe that food enables biological processes (Inagaki & Hatano, 1996), it was additionally explained that different processes require different nutrients. Children learned and generalized this new theory: over half described the role of blood in transporting food when answering open-ended questions about digestion, almost all claimed there were invisible nutrients inside of food, and nearly half justified their hypothetical snack choices in terms of nutrients or variety. Moreover, children even increased their vegetable consumption during snack time even though eating more vegetables was not explicitly mentioned in the intervention.

In the present research, we lay the groundwork for using such an intuitive theory based approach for motivating adults to exercise by taking stock of adults' theories regarding exercise. New findings in exercise research show profound and broad-ranging benefits of exercise, from increasing insulin sensitivity (Borghouts & Keizer, 2000), to regulating the immune system and reducing inflammation (Woods, Vieira, & Keylock, 2009), to warding off depression (Dunn, Trivedi, Kampert, Clark, & Chambliss, 2005; Salmon, 2001) and even decreasing the risk for dementia among the elderly (Kramer, Erickson, & Colcombe, 2006; Hillman, Weiss, Hagberg, & Hatfield, 2002; K. Erickson & Kramer, 2008). Though research is just beginning to delineate the specific mechanisms behind these benefits, the general explanation seems to be that the body sets in motion a cascade of biochemical processes that are specially adapted to sustain and repair body and brain cells and prepare them for the next physical challenge. This repair process explains why exercise improves such a wide range of health indicators, and even causes the creation of new brain cells. Exercise is more than just physical movement: it is in many ways like taking medicine.

We begin by asking what theories adults draw upon to reason about exercise. Very little research exists to guide us

in characterizing these theories. However, we expect non-expert adults to explain the benefits of exercise by appealing to causal mechanisms that are more or less mechanical in nature; e.g., the heart works harder and thus propels more blood throughout the body; muscles physically grow larger as they become stronger; calories are used up and thus the amount of fat on the body is reduced. Under this view, health benefits would appear to result from biomechanical factors such as weight loss and increased strength of the muscles and heart.

If adults indeed do hold a predominantly biomechanical theory of exercise, we suspect that this theory will be inadequate to explain many of these recently-discovered benefits of exercise satisfactorily. Mental benefits, such as the reduced risk for dementia and improvements in cognitive ability should be especially problematic, because they cross a well-worn ontological boundary between the biological and psychological domains (see, e.g., Carey, 1987; Wellman & Gelman, 1992, 1998; Inagaki & Hatano, 1993; Erickson, Keil, & Lockhart, 2010; Lynch & Medin, 2006). For example, a normal-weight, or even thin, elderly person who is concerned about memory loss might be more likely to seek out crossword puzzles than physical exercise. An overweight person who embarks on an exercise program and fails to lose a significant amount of weight despite hard work may despair of receiving any health benefits. The present research seeks to document the theories that adults bring to bear on explaining the benefits of exercise as a first step towards creating an intuitive theory based intervention designed to communicate the newfound benefits of exercise to adults.

Experiment 1

Experiment 1 explores 3 questions: (1) To what extent do adults evoke biomechanical, biochemical, and other causal mechanisms to explain the effects of exercise on the body? (2) How plausible do adults find physical and mental effects of exercise? (3) Do adults view physical benefits of exercise as contingent on weight loss?

Methods

Participants Participants were 50 adults (27 women) from the United States recruited through Amazon's Mechanical Turk (AMT). Ages ranged from 18-25 years ($N = 9$) to 60-69 years ($N = 2$).

Survey A survey was designed using Qualtrics. Question blocks were presented in a fixed order (i.e., plausibility ratings, explanation of benefits, importance of weight loss, and explanation of benefits without weight loss), but items were always randomized within blocks.

Plausibility Ratings Participants were given a list of claims about the effects of exercise and asked to rate their agreement on a scale of 0 - 100 with their mouse using a slider. The endpoints of the scale were labeled "totally disagree" and "totally agree," and the midpoint was labeled "neither agree nor disagree." Items included 2 physical effects (improved blood pressure, increased heart rate), 2 emotional

effects (reduced depression risk, improved mood), and 2 cognitive effects (reduced risk for memory loss, improved problem-solving ability). Finally, half of the effects were framed as short-term (immediately after exercise, people experience increased heart rate, improved mood, and improved problem-solving ability) and half as longer-term (regular exercise helps improve blood pressure, reduce depression risk, and reduce risk for memory decline).

Explanation of benefits Participants were shown claims about the benefits of exercise and asked questions framed as, "Research shows that getting regular physical exercise can [claim about benefit]. If you had to guess, why would you say getting plenty of exercise [claim about benefit]?" Participants were asked to assume the claims were true and provide the best explanations they could. Items included 2 physical (reduced blood pressure / blood sugar), 2 emotional (reduced depression risk, reduced stress), and 3 cognitive benefits (improved memory, improved problem-solving ability, and reduced risk for dementia).

Importance of weight loss Seven questions asked whether participants saw value in exercise apart from weight loss. Participants rated how much they agree or disagree with 7 statements such as, "If someone exercises regularly for a long time and never loses any weight, they are probably wasting their time" on a scale of 1-100 using a sliding scale.

Results and Discussion

Results did not differ by age and gender, so results are collapsed across these categories.

Plausibility Ratings Figure 1 presents mean agreement ratings for each effect of exercise. All ratings were significantly greater than the "neither agree nor disagree" midpoint (all t 's > 3.2), demonstrating that all effects were more plausible than not. Ratings were arcsine transformed to ensure homogeneity of variance and compared to one another using a repeated-measures ANOVA with within-subjects factors of item type (physical, emotional, and cognitive) and time scale (long vs. short-term). Results revealed a main effect of item type ($F[2, 48] = 50.53, p < .0001$) and a significant item type by time scale interaction ($F[2, 48] = 11.28, p < .0001$). Post-hoc paired t -tests showed that emotional effects were less plausible than physical effects (physical $M = 90.8\%$ agreement rating, emotional $M = 80.9\%$ agreement rating, $t(49) = 6.09, p < .0001$), and cognitive effects ($M = 66.5\%$ agreement rating) were less plausible than emotional ($t(49) = 6.14, p < .0001$) and physical ($t(49) = 9.75, p < .0001$) effects. No differences were observed between long - and short-term items within physical and emotional effects (t 's < 1.8), but improving immediate problem-solving ability ($M = 60.1\%$ agreement rating) was less plausible than reducing risk for dementia ($M = 72.8\%$ agreement rating).

Explanations of benefits Tables 1-3 present summaries of participants' open-ended explanations. Responses were

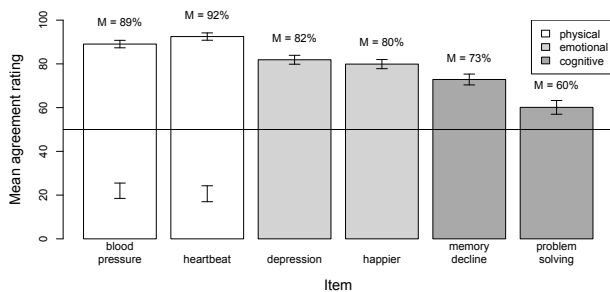


Figure 1: Mean plausibility ratings by items. Error bars represent standard error of the mean.

coded into one or more categories.

Physical benefits Explanations for physical benefits included biomechanical mechanisms such as circulation (improved/increased blood flow), “burning off” sugar/calories, clearing debris from blood vessels, strengthening the heart and/or blood vessels, and reducing weight; non-biological explanations (e.g., exercising helps people develop better health-related habits, self-discipline, confidence, etc.); biochemical explanations; and ambiguous biological explanations such as increasing metabolic rate. Table 1 presents the proportion of participants whose explanations featured each category. Biomechanical explanations were by far the most common.

Items (2)	blood pressure	blood sugar
burns sugar / calories	0.00	0.52
weight	0.24	0.26
circulation	0.36	0.08
stronger heart	0.34	0.00
clears blood vessels	0.12	0.00
biochemical	0.00	0.12
metabolism	0.00	0.12
non-biological	0.02	0.08
other	0.34	0.30
dk	0.00	0.02

Table 1: Proportion of participants appealing to each explanation type for 2 *physical benefits* of exercise: reducing blood pressure and blood sugar

Emotional benefits Table 2 presents a summary of explanations for the effect of exercise on stress and depression. A handful of biomechanical explanations were observed, such as improved circulation (4% and 2% for depression and stress) and the release of stress, tension, or negative energy (38% for stress only). However, explanations for stress and depression most commonly appealed to biochemical explanations (52% and 30% for depression and stress) and non-biological explanations (52% and 30% for depression and stress).

Items (2)	depression	stress
non-biological	0.52	0.32
biochemical all	0.50	0.30
release	0.00	0.38
relax tire out	0.00	0.12
circulation	0.04	0.02
other	0.12	0.12
dk	0.00	0.00

Table 2: Proportion of participants appealing to each explanation type for 2 *emotional benefits* of exercise: preventing depression and reducing stress

Cognitive benefits Table 3 presents a summary of explanations for cognitive benefits of exercise. As with physical benefits, participants appealed predominantly to biomechanical mechanisms such as circulation (improved blood or oxygen flow to brain and other tissues) and the brain itself getting a “workout” during physical exercise. Participants also claimed that exercise increases feelings of awakesness and improves overall health, and also offered non-biological explanations (e.g., exercise increases social activity, mental discipline, willpower, etc.), and a few biochemical explanations.

Items (3)	dementia	memory	problem solving
circulation	0.52	0.62	0.40
nonbio	0.18	0.16	0.20
alert clear head	0.00	0.14	0.22
physical health	0.18	0.10	0.08
exercises brain	0.14	0.12	0.06
other	0.10	0.10	0.08
biochemical	0.10	0.10	0.04
dk	0.06	0.00	0.02

Table 3: Proportion of participants appealing to each explanation type for 3 *cognitive benefits* of exercise: preventing dementia, improving memory, and improving problem-solving ability

Biochemical explanations Table 4 presents a summary of biochemical explanations across items. While participants mentioned a wide variety of biochemicals, the most commonly-mentioned was endorphins.

Summary of explanations of benefits Participants evoked primarily biomechanical explanations for physical and cognitive benefits of exercise, and primarily biochemical and non-biological explanations for emotional benefits. This suggests that although many participants are aware of some biochemical processes related to exercise, they do not view the physical, cognitive, and emotional benefits of exercise as consequences of a single cascade of adaptive biochemical responses. Interestingly, biochemical explanations were overwhelmingly offered for emotional benefits, rather than phys-

Benefit type	Explanation type	Item	conditional % of participants
physical emotional	insulin	blood sugar	1.00 (6 of 6)
	endorphins	depression	0.54 (14 of 26)
		stress	0.67 (10 of 15)
	general chemicals	depression	0.31 (8 of 36)
		stress	0.13 (2 of 15)
	hormones	depression	0.08 (2 of 26)
		stress	0.13 (2 of 15)
serotonin	depression	0.19 (5 of 26)	
	stress	0.07 (1 of 15)	
cortisol	stress	0.13 (2 of 15)	
	cognitive	endorphins	problem-solving 0.50 (1 of 2)
general chemicals		dementia	0.40 (2 of 5)
		memory	0.40 (2 of 5)
hormones		problem-solving	0.50 (1 of 2)
		dementia	0.40 (2 of 5)
neuro-transmitters		memory	0.20 (1 of 5)
		dementia	0.20 (1 of 5)
build new brain cells	memory	0.20 (1 of 5)	
endorphins	memory	0.20 (1 of 5)	

Table 4: Breakdown of biochemical explanations by benefit type (cognitive, emotional, and physical) and item (preventing depression, reducing stress, etc.). Presented as a conditional proportion of total biochemical explanations given for each item.

ical or cognitive ones, and the vast majority cited endorphins as the causal mechanism. We therefore suspect many of these biochemical explanations may reflect awareness of the well-publicized “runners’ high.”

Importance of weight loss Reliability among the 7 questions about the importance of weight loss was high (Cronbach’s alpha = .93) and so a composite importance-of-weight score was created, $M = 23.2$ out of 100, $sd = 14.2$. This score was significantly lower than the “neither agree nor disagree” midpoint of the scale, $t(49) = 13.34$, $p < .0001$, indicating that participants do not view exercise as beneficial solely in the presence of weight loss.

Biochemical explanations in relation to other measures To see whether participants who appealed to biochemical causal mechanisms viewed weight loss as less important, we divided participants into two groups: one who never offered biochemical explanations ($N = 18$), and one who did ($N = 30$). Participants who offered a biochemical explanation had lower importance-of-weight scores ($M = 19.1$) than participants who did not ($M = 29.5$, $t[46] = 2.56$, $p = .02$). We also asked whether participants who offered at least one biochemical explanation rated cognitive and emotional benefits

of exercise as more plausible than participants who offered none, and found that they did not, t ’s < 1.3 .

Discussion

Experiment 1 provided preliminary evidence that adults find the cognitive effects of exercise are less plausible than emotional effects, and emotional effects less plausible than physical effects. Furthermore, we provided preliminary evidence that adults appeal predominantly to biomechanical explanations for explaining the physical and cognitive benefits of exercise, but not the emotional benefits. Instead, adults frequently gave biochemical and non-biological, rather than biomechanical, explanations for the emotional benefits of exercise. However, we suspect these biochemical explanations represent isolated facts, rather than a coherent biochemical theory of the body’s response to exercise. Nevertheless, awareness of at least some biochemical effects of exercise in the could be used as leverage for teaching a more coherent biochemical theory.

Finally, although participants were reluctant to endorse statements that blatantly identify weight loss as the primary source of exercise-related health benefits, participants who gave at least one biochemical explanation viewed weight loss as less of a critical factor than participants who identified none. However, it is possible that although adults concede that exercise *can* offer benefits aside from weight loss, they may still view achieving a healthy weight as important gauge of success if given more subtle questions. Experiment 2 tests this possibility.

Experiment 2

Experiment 2 explores more closely the importance adults place on maintaining a healthy weight when gauging exercise-related health benefits.

Methods

Participants Participants were 47 adults (23 women) from the United States recruited via AMT. Ages ranged from 18-29 ($N = 23$) to 50-59 ($N = 4$).

Survey A survey was designed using Qualtrics. Blocks were presented in a fixed order (i.e., open-ended health behaviors, thinness vs. fitness, weight loss vs. no weight loss), but items within blocks were randomized.

Open-ended health behaviors Participants were asked to list what they believe are the best ways to stay healthy. We were interested in whether participants would be more likely to list maintaining a healthy weight than exercise on its own.

Thinness vs. fitness Participants indicated which of two hypothetical people would be healthier: someone with a healthy weight who rarely exercises and has low physical fitness, or someone who is overweight, exercises frequently, and has high physical fitness.

Exercise vignettes: weight loss vs. no weight loss Participants viewed two vignettes about characters who are overweight and begin fitness programs. Both work out 4-5 times per week for 30-40 minutes each time for a year. However, one character achieves a weight near the healthy range, and the other character only loses a few pounds and remains overweight. Participants estimated the percent likelihood that each character received a set of physical, cognitive, and emotional benefits. Order was randomized across participants.

Results and Discussion

Results did not differ by age and gender, so results are collapsed across these categories.

Open-ended health behaviors Table 4 presents behaviors participants identified as important for health. Nearly all participants identified exercise and diet. No participants identified maintaining a healthy weight.

	% of participants
healthy diet	1.00
exercise	0.96
weight loss	0.00

Thinness vs. fitness 15% of participants said that a person who is lean and not physically fit is healthier than someone who is fit and overweight. 23% of participants said both are equally healthy, and 61% said that an overweight, fit person is healthier, $\chi^2(2) = 16.2, p = .0003$.

Exercise vignettes: weight loss vs. no weight loss Reliability across likelihood ratings for physical, cognitive, and emotional benefits was high ($\alpha = .93$ for no-weight-loss vignettes and $.92$ for weight-loss vignettes) mean composite score for each vignette was computed for each participant across items. Participants rated benefits as significantly more likely in the presence of weight loss (no-weight-loss vignettes $M = 56%$ likely, weight-loss vignettes $M = 72%$ likely, $t[46] = 6.8, p < .0001$).

Because the vignettes were identical except for weight loss, it was possible that participants used weight explicitly to differentiate their ratings. We therefore performed a between-subjects comparison using only each participant's *first vignette*. Figure 2 presents these ratings. Again, participants rated benefits as more likely when they occurred in the presence of weight loss ($M = 76%$ likely) than in the absence of weight loss ($M = 65%$ likely), $t(45) = 2.4, p = .02$.

This suggests that adults do at least to some extent view weight loss as an indication of progress in an exercise program. This was true for nearly every benefit we presented, including physical and emotional benefits.

Discussion

Participants identified diet and exercise as the best ways to improve health nearly 100% of the time, and they recognized

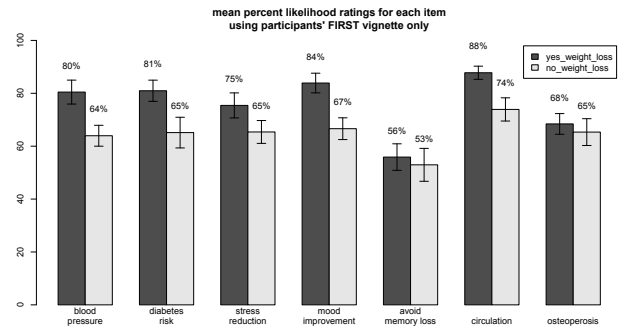


Figure 2: Ratings of percent likelihood that the character in each vignette experienced each benefit. Considering *only each participant's first vignette*

that a fit, overweight person is likely to be healthier than a normal-weight, unfit person. On the other hand, participants rated nearly all of the benefits of exercise that we presented as less likely to occur for a character who loses very little weight. It is possible that participants found it implausible that a character could truly comply with an exercise program for a year and not lose weight. Exercise physiology research has shown, however, that some individuals do comply rigorously with an exercise program but lose very little weight, and yet still reap health benefits similar to those who lose more weight (King, Hopkins, Caudwell, Stubbs, & Blundell, 2009). The vignettes furthermore gave identical descriptions of both exercise regimens. Participants still may have assumed the non-weight-loss character was not working out as *intensely*, however. Further research is needed to determine whether adults view weight loss as a *mechanism* behind certain health benefits, or as *diagnostic* of adequate effort.

General Discussion

These studies to our knowledge provide the first systematic exploration of how adults bring their biological theories to bear on the topic of exercise. Although many participants were aware of some biochemical effects of exercise, we did not find evidence of participants holding coherent theory of exercise triggering a cascade of beneficial chemical responses in the body.

Although adults do not view weight loss as more important than exercise, we found that they do view many benefits as less likely to occur without weight loss. A biochemical theory of exercise may therefore be useful to de-emphasize weight loss as a gauge or mechanism for health benefits.

We also identified one area in which biochemical effects of exercise are already well-known: the emotional benefits of exercise. Widespread knowledge of the "runner's high" can therefore be leveraged to teach a more general biochemical theory of exercise.

Finally, we identified one way in which a biochemical theory of exercise may fail to support a coherent understanding of the wide-ranging benefits of exercise. Adults view cog-

nitive benefits of exercise as less plausible than physical and even emotional benefits. They also explain cognitive benefits primarily by appeal to biomechanical explanations—few participants offered biochemical accounts. This raises the interesting possibility that a lay biochemical theory of exercise does not support a coherent, compelling explanation for the cognitive benefits of physical exercise. This may have implications for motivating older adults to exercise. Maintaining cognitive acuity may be much more important to older adults than more well-known aims of exercise such as building strength and improving physical appearance. At the same time, these cognitive benefits may be the most difficult to understand in light of adults' lay theories. An intervention that explains the cognitive benefits of exercise may therefore be especially useful if targeted towards older adults.

Future research will test whether teaching adults a biochemical theory of exercise increases their conviction about the cognitive benefits of exercise, diminishes focus on weight as an indicator of success, and *actually motivate adults to exercise more*. The present research documents adults' lay theories of exercise and establishes the potential utility of an intuitive theory based approach to motivating adults to exercise.

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