A Review of Web-Based Dietary Interventions

From the Human-Computer Interaction Practitioners' Perspective

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Abstract

Despite the popularity of web-based dietary interventions, there are few evidence-based, practical guidelines that help human-computer interaction (HCI) practitioners design new dietary intervention systems. We suspect that a lack of such guidelines is partly due to a chasm between two major research domains, healthcare and HCI. We believe that technologies developed in HCI are not used and evaluated by healthcare researchers, so we fail to accumulate experiences to develop guidelines. In order to assess the gap, we carefully selected 86 papers that employed and evaluated various web-based dietary interventions in both fields, and analyzed general characteristics, behavior change strategies, intervention media, and research outcomes used in each paper. Through this review, we reaffirmed our belief about the discrepancies between healthcare and HCI, and additional findings helped us offer some suggestions to close the gap. We also identified several interesting patterns among behavior change strategies, intervention media, and outcomes, which provide potential topics for future research.

1 Introduction

Web-based intervention is a widely adopted approach to promote healthier dietary behavior change because of its advantages over traditional media; such advantages include low cost, wide dissemination, and interactivity. Though some of these interventions are simply the dissemination of healthcare information through static web documents (Porter, Chapman-Novakofski, & Scherer, 2009), more sophisticated approaches, such as an interactive virtual coach (Bensley et al., 2006), also have been developed and adopted. Many researchers and practitioners in healthcare and human-computer interaction (HCI) have attempted to employ web-based interventions to promote dietary behavior changes, with the expectation that the behavior changes will eventually lead to improvements in actual health outcomes.

Despite the success of web-based dietary interventions (Wantland, Portillo, Holzemer, Slaughter, & McGhee, 2004), there are only few comprehensive and practical guidelines for HCI practitioners. We do find some survey studies that reviewed existing studies and provided interesting insights about how to promote behavior changes through various strategies, such as tailoring (e.g., Bourdeaudhuij, Stevens, Vandelanotte, & Brug, 2007; Kroeze, Oenema, Campbell, & Brug, 2008), monitoring (e.g., Beach, Briggs, Shahrani, & Elliott, 2006), and social support (e.g., Tate, Jackvony, & Wing, 2006; McKay, Glasgow, Feil, Boles, & Barrera, 2002). Though these studies regarding behavior change strategies are insightful, they do not sufficiently provide practical, easy-to-use details that are necessary to HCI practitioners. HCI practitioners may still have following questions after learning about these strategies: Which media or technologies will be more appropriate to implement one of strategies, say "social support," email or discussion board? If we use email, what kinds of information should be provided in the email?

Thus, our ultimate goal is to provide comprehensive and practical guidelines that HCI practitioners can readily use in designing web-based dietary intervention systems. In order to achieve this goal, we comprehensively reviewed and analyzed 86 relevant papers from the perspective of HCI researchers and practitioners. However, we quickly noticed that our ultimate goal is challenging to achieve. We constantly ran into two distinctive kinds of papers: one group of papers reported rigorous evaluation studies without details of employed interventions; the other group of papers described technical details, but they did not report rigorous evaluation studies. Due to the gap between these groups of papers, it is almost impossible to provide comprehensive guidelines that are both practical and evidence-based. We also realized that this discrepancy between two groups of papers are mainly due to differences in academic culture of

the two contributing domains: healthcare and HCI.

After realizing this limitation, we adjusted our goal of this paper. Instead of providing the ultimate guidelines, we focused on the gap between two healthcare and HCI and attempted to understand how these two fields are different as academic disciplines. Then, we tried to offer several suggestions to both fields to close the gap. As you may expect, the gap was initially perceived as a big hurdle for us, but we gradually realized that the gap begets lots of research opportunities for both healthcare and HCI researchers, so we try to identify these opportunities. Though our ultimate goal is only partially achieved in this paper, we believe that this study still provide interesting insights for many researchers working on web-based dietary interventions.

This paper is organized as follows. In Section 2, relevant literature is briefly reviewed to provide the overview of studies regarding designing web-based dietary interventions. In Section 3, the methods to collect and code the relevant literature are detailed. In Section 4, the results of analysis are presented. In Sections 5 and 6, the implications of results and future research are discussed.

2 Background

Multiple review studies investigate the effects of behavior change strategies on dietary behavior changes. For example, some studies emphasize that healthcare information should be tailored depending on individual needs (Rimer & Kreuter, 2006; Lustria, Cortese, Noar, & Glueckauf, 2009), and some others showed the effects of monitoring (Siu, Chan, Poon, Chui, & Chan, 2007; Kubiak, Hermanns, Schreckling, Kulzer, & Haak, 2006) and social support (Thijs, 2007). Recently, some review papers start to investigate these issues more comprehensively. Abraham and Michie (2008) proposed a taxonomy of behavior change strategies. Webb et al. (2010) extended the taxonomy and investigated the effects of strategies, theories, and delivery methods of Internet-based interventions on health outcomes.

However, as discussed in the Introduction section, we noticed two general limitations of these studies:

First, most of them tend to focus on one specific behavior change strategy. Though some of them comprehensively review multiple strategies and investigate their effects (Abraham & Michie, 2008; Webb et al., 2010; Hur, Kwon, &

Yi, 2010), they also did not provide what are the effects of combinations of those strategies. Given the fact that most of interventions actually employ multiple behavior change strategies simultaneously, this is an important missing piece.

Second, they failed to provide details of how these strategies are implemented in their interventions, so it would be difficult to replicate and evolve the successful interventions. Webb et al. (2010) provided a taxonomy of mode of delivery and assess their effects using a meta analysis. According to their study, "text message" and "access to an advisor" are ones that are highly effective mode of delivery, but such information is still not sufficient to be used by HCI practitioner practically. Hur et al. (2010) attempted to provide some reviews for the technological details, yet the goal was not fully reached.

3 Methods

3.1 Selection of Papers

We extensively surveyed research papers on web-based dietary intervention published in peer-reviewed journals and conference papers between year 2001 and 2010. The following electronic journal archives were reviewed: Medline, Science Direct, Springer, IEEE Xplore, and ACM Digital Library. Keywords searched in abstracts and titles of papers were every possible combination of terms from each block: (Block1: "internet," "web," "WWW," "online," "mobile"), (Block2: "dietary," "nutrition," "overweight," "obesity," "diabetes"), and (Block3: "intervention", "program," "tool," and "system"). With these combinations of keywords, we initially identified 771 papers. Explicit exclusion criteria were employed to further refine the selection as summarized in Table 1: First, we reviewed the titles or abstracts of the papers to determine their eligibility for the review. We excluded survey papers that review other literature because they do include multiple studies in a single paper (Exclusion 1). Second, we excluded papers that do not involve the actual dietary intervention programs (Exclusion 2). For example, we excluded the papers specifically focusing algorithm (e.g., Bo, Le, Xiu-e, & Juanjuan, 2008) or methodology (e.g., Lo, Cheng, & Chen, 2008) without having a particular intervention. Third, we checked if the interventions were web-based systems (Exclusion 3). We interpreted the term "web-based" rather broadly because we noticed that boundary between web technologies another other information technologies are often blurred. As a result, we included any techniques using the Internet, such as mobile

technologies (Tanguay & Heywood, 2007). Fourth, we excluded papers that included only non-dietary interventions (Exclusion 4). For example, we excluded papers only dealing with physical exercise and blood control even though we include papers that include non-dietary interventions on top of dietary interventions. Last, we iteratively evaluated the remaining papers to create the final list based on the description of intervention media (Exclusion 5). For instance, we excluded papers that do not have any description of their intervention website. We also excluded papers which we had no access to its actual manuscripts. Eventually, total 86 papers (62 papers in healthcare and 24 papers in HCI) were chosen for the review, which we call "paper pool," henceforth.

Table 1: Paper exclusion criteria and the resulting numbers of papers.

Phase	Number of papers
Initial survey of papers using search engines	771
Exclusion 1: Survey papers	-128
Exclusion 2: Irrelevant topic	-76
Exclusion 3: Not a web-based system	-57
Exclusion 4: Not diet (only exercise, blood)	-334
Exclusion 5: No sufficient description of technologies; Failure to access full text	-90
Final paper pool	86

3.2 Coding

Two leading authors coded the selected papers independently. To ensure a consistent and systematic coding process, we took the following steps: First, the two coders coded ten randomly selected papers, and the results of coding were compared and discussed in order to make sure that both coders understood the coding scheme properly and applied it consistently. Then, the rest of the paper pool was coded, and several discussion sessions were held as coding progressed. Inter-rater reliability between the two coders was generally high (Cohen's Kappa was 56.63%, and the percentage of agreement was 82.95%, but if there were any discrepancies in coding results, such areas were revisited to make final agreements.

Codes used for each paper fell into four categories: 1) general characteristics, 2) behavior change strategies, 3) intervention media, and 4) research outcomes.

General characteristics of papers include the study objective, the target population of the intervention, the number

of human subjects, the venues of the publication, and authors' affiliations. We expected that such information would provide some insights on some of the questions we had, such as who the main contributors in the field are and what kinds of evaluation practices are most popular. Note that the venues of the publications and authors' affiliations are coded using three categories (healthcare, HCI, and mixed) in order to investigate the levels of collaboration between the two fields. When we code the theory aspects of studies, we ruled out theories that are not relevant to dietary intervention (e.g., fuzzy theory and technology probes).

Behavior change strategies are strategies used in a study to change behaviors of the target population. We initially relied on a taxonomy of behavior change strategies developed by Abraham and Michie (2008) and extended by Webb et al. (2010). The extended version of Webb et al. (2010) suggested 40 categories of behavior change strategies. However, we later found that a half of the 40 strategies were not used in our paper pool, so we ended up using a subset of the taxonomy with 20 behavior change strategies, as shown in Table 2. Though most of the strategies are self-explanatory, some caused confusion. For example, in the early phase of coding, "Prompt Self-Monitoring Behavior" and "Prompt Self-Monitoring Of Behavioral Outcome" were interpreted differently by the two coders. However, these instances of confusion were clarified through discussion sessions, so we later clarified that "Prompt Self-Monitoring Behavior" is a strategy that asks a person to keep a record of *specified behavior(s)* (e.g., the frequency of eating junk food), and "Prompt Self-Monitoring Of Behavioral Outcome" is a strategy that asks a person to keep a record of *outcomes due to behavior changes* (e.g., weight changes due to eating junk food).

Intervention media are communication methods used in web-based interventions to deliver information to the target population; such intervention media included are not limited to email and online bulletin boards. We are particularly interested in what kinds of intervention media were used in the paper pool and how they are related with behavior change strategies because such information would help HCI practitioners design actual websites. Unfortunately, we failed to find comprehensive taxonomy for intervention media used in web-based dietary interventions, so we first collected all the descriptions of used intervention media without coding, and later the collected descriptions were analyzed to propose a taxonomy of intervention media. We also noticed that some non-digital intervention media (e.g., phone call and mail/brochure) were used in our paper pool often with other digital-intervention media, so we categorized the collected intervention media into digital and non-digital intervention media, which eventually further

refined into 12 and 4 categories of intervention media, respectively. The detailed list of intervention media can be found in Table 8.

In addition, we also noticed that the levels of descriptions of intervention media vary substantially among papers. Some papers provide the detailed description of the intervention's functionalities and how potential users use these functionalities with a series of screen shots. In contrast, other papers briefly mention their intervention without details. Since the detailed descriptions of employed interventions are crucial for HCI practitioners to replicate and understand the interventions, we would like to systematically understand how much details each paper provide. Since we failed to find any relevant literature, we developed our coding scheme as we reviewed papers. We found that the following four elements are appropriate to understand each intervention: 1) functional descriptions (e.g., what kinds of media were used and how media delivered contents to users); 2) the explanation of which behavior change strategies are supported and how they are supported; 3) use cases describing how a user would use the intervention media; and 4) screen shots showing the intervention media. Even though the levels of details vary widely, the presence and absence of each element was binarily coded to minimize subjectivity.

Outcome measurements are coded to investigate whether a certain behavior change strategy or intervention medium is actually effective or not. We noticed that different papers collected different types of outcome measures. We categorized them into one of four types: change of behavior intention (BI), change of behavior (BC), change of knowledge level (K), and health improvement (HI). BI captures changes in the motivation of users toward healthy behaviors. The concept of BI can be found in Social Cognitive Theory (Bandura, 1985), the Theory of Reasoned Action (Sheppard, Hartwick, & Warshaw, 1988), the Theory of Planned Behavior (Ajzen, 1991), and the Transtheoretical model (Prochaska & Velicer, 1997). Examples of BI measures include intentions to behave, satisfaction, and self-confidence with respect to the behavior (Block, Block, Wakimoto, & Block, 2004; Glasgow, Boles, McKay, Feil, & Barrera, 2003). In contrast, BC captures actual changes in behavioral patterns by measuring various outcomes such as fruit and vegetable consumption, fat intake, and energy intake. K is an indicator of how well a participant understood and learned the relevant knowledge related to dietary intervention. Perceived risks of benefits and harms are examples of K. HI measures includes, but are not limited to, changes in weight, BMI, and HDL-cholesterol level that captures the physical healthiness.

Table 2: The list of behavior change strategies used to analyze papers.

Behavior Change Strategies[1]
Action Planning
Agree Behavioral Contract
Barrier Identification/Problem Solving
General Communication Skills Training
Goal Setting (Behavior)
Goal Setting (Outcome)
Model/Demonstrate The Behavior
Motivational Interviewing
Plan Social Support/Social Change
Prompt Self-Monitoring Behavior
Prompt Self-Monitoring Of Behavioral Outcome
Provide Feedback On Performance
Provide Information On The Consequences For Individual
Provide Information On The Consequences In General
Provide Instruction
Provide Normative Information About Others' Behavior
Provide Rewards For Behavior
Reinforcing Effort Toward Behavior
Relapse Prevention/Coping Planning
Stress Management

[1] Details of the behavior change strategies can be found at (Abraham & Michie, 2008; Webb et al., 2010).

After categorizing measurements into the four measurements, we evaluated evaluation outcomes either positive or non-positive. We used 'non-positive' rather than 'negative' because no paper in the paper pool reported totally negative outcomes. Their outcomes are either statistically not significant or mixed (showing both significantly positive and negative). For controlled studies, we could easily determine whether the outcome is positive or negative according to their statistical results, but some studies used qualitative methods. In this case, we coded outcomes based on their qualitative conclusions. We marked these cases separately using underscores in Table 5.

During the coding process, we noticed that some papers include multiple interventions simultaneously. For example, Tate et al. (2006) conducted evaluation studies with one control conditions and two treatment conditions: "no counseling (control)," "human e-mail counseling (treatment 1)," and "computer-automated for tailored feedback (treatment 2)." Since we used the number of papers as a metric to show the frequency of a certain characteristics (e.g., 62

papers employed the "Provide Instruction" strategy), having multiple interventions in a single paper could complicate data analysis. Thus, we decided to only use the results comparing the most sophisticated condition to the control condition and did not consider other conditions. In the example of Tate et al. (2006), we only used the results comparing the "no counseling" condition (control) and the "computer-automated for tailored feedback" condition (treatment 2). We intentionally ruled out the result of the "human e-mail counseling" condition (treatment 1).

3.3 Data Analysis

We initially considered applying meta analysis for this review study. Meta analysis is a widely adopted approach to summarize multiple quantitative research findings (Lipsey & Wilson, 2001). Some review studies employ meta analysis to investigate web-based intervention studies (e.g., Webb et al., 2010). However, our paper pool has too diverse dependent variables (see Table 3) and many independent variables (see Table 2). In addition, we also would like to embrace qualitative studies (e.g., Grimes, Bednar, Bolter, & Grinter, 2008) and studies without clear evaluation outcomes (e.g., Fudholi, Maneerat, & Varakulsiripunth, 2009). Due to the diversity of collected studies, we found that meta analysis and many other statistical approaches (e.g., regression analysis and correlation test) are inappropriate. Thus, we decided to focus on describing patterns that are identified through simple frequencies, rather than reporting results of sophisticated statistical analysis. We believe that simple statistics may provide a clearer picture of the general trends in our paper pool.

We reported the number of papers as main measurements across all results and frequency, mean, and percentage for some measurements to reveal the pattern. We counted the number of papers that fall into general characteristics, such as publication venues, study types, and the number of participants, that we collected from the papers. We also counted the number of papers that included each behavior change strategy, intervention media, and outcome measurement. In addition, we also counted papers that included a pair of each behavior change strategy, intervention media, and outcome measurement. We also counted papers that included a combination of two different categories, such as a behavior change strategy and an intervention medium. For all measurements related to behavior change strategy, intervention media, and outcome measurements, we also reported frequency, mean, and percentage to highlight the trend.

4 Results

4.1 General Characteristics

One of the most salient patterns we found in general characteristics is that there is a strong distinction between papers in HCI-related publication venues, such as *IEEE Pervasive Computing* and *Annual SIGCHI Conference on Human Factors in Computing Systems* (often called CHI) (HCI papers, henceforth), and papers in the healthcare-related publication venues, such as *Obesity*, *Patient Education and Counseling*, and *Health Education Research* (healthcare papers, henceforth). The paper pool contains more healthcare papers (62 papers) than HCI papers (24 papers). In addition, rigorous evaluation appears to be more emphasized in healthcare papers. More HCI papers omitted evaluation (18 out of 24 papers) than healthcare papers (8 out of 62 papers). Out of 24 HCI papers, 7 HCI papers did not specify the target population, and 13 HCI papers targeted the general population without specifying types of population, such as people with obesity and children. On the other hand, healthcare papers had diverse but specific target populations, as shown in Table 3. Despite the large variance, the average number of participants in healthcare (average 1237 persons) was much larger than that of HCI (average 29 persons). Healthcare papers tended to take longer duration (average 36 weeks) to conduct evaluation studies than HCI (average 5 weeks). Healthcare papers more frequently used direct health measurements (e.g., weight, dietary intake, body mass index, cholesterol, and blood pressure) than HCI studies as shown in Table 3.

Some additional interventions (i.e., physical exercise and medical care) combined with dietary interventions were employed and showed some positive effects on health outcomes. There are 33 papers that exclusively employed dietary interventions, such as nutrition treatment, but the other 53 papers included not only dietary intervention but also other interventions (exercise, medical care, or both) as shown in Table 4. The table also shows the numbers of papers reporting positive results divided by the total number of papers with evaluation studies in four outcome variables (BI, BC, K, and HI). We intentionally present the frequency information in the form of fractions because presenting simple relative values could mislead readers. For example, we do not want readers to believe that one positive result out of one evaluation study means 100% positive results. However, we provide relative values in body text whenever they are appropriate. Eleven papers reported evaluation studies that investigated the effects of diet-only interventions, 9 out of

Table 3: General characteristics of HCI and healthcare papers.

Categories	**HCI**	**Healthcare**
Number of papers	24	62
Affiliations[1]	18 out of 24 papers are authored only by HCI researchers.	61 out of 62 papers are authored only by healthcare researchers.
Target Populations[2]	General Population (12); Obese/Overweight (1); Diabetes Patient (4); Adolescents (0); Children (0); and Undefined (7)	General Population (22); Obese/Overweight (14); Diabetes Patient (8); Adolescents (11); Children (2); and Undefined (5)
Average Number of Participants	29 persons	1237 persons
Average Duration of Evaluation	5 weeks	36 weeks
Theories/Models directly employed to design interventions[2]	Technology Probes (1) and Spiral Lifecycle Model (1) (Note that these theory and model were not directly employed to design interventions but are more like general research and development methods (Mamykina, Mynatt, Davidson, & Greenblatt, 2008; Beach et al., 2006).)	Social Cognitive Theory (9), Transtheoretical Model (7), Theory of Planned Behavior (3), eHealth Behavior Management Model (2), Cognitive Behavioral Theory (2), Stage of Change Theory (2), Self-efficacy Theory (2), Tailored Self-management Theory (2), Social Cognitive Theory (2), Self-directed Behavior Change Theory (1), Motivational Interviewing (1), Elaboration Likelihood Model (1), Lifestyle Intervention Program (1), Wise Mind Theory (1), National School Lunch Program (1), Goal-setting Theory (1), Social Ecological Model (1), Proximal Leverage Point (1), Brofenbrenner's Ecological Model (1)
Health-related outcome measures[2]	Health Locus of Control (1), Diabetes Quality of Life (1), Fat Scale (1), Sphygmomanometer (1), Calorie Consumption (1)	Weight (30), Dietary Intake (15), Height (12), BMI (12), Waist Circumference (7), Fat Scale (6), Cholesterol (6), Blood Pressure (5)
Non-health-related outcome Measurements[2]	Qualitative Measures (2), Log/Usage Data (2)	Log/Usage Data (7), Social Support Scale (6), Program Adherence (5), Stage of Change (3), Weight Concern (2), Income (2)

[1] 7 papers have co-authors from both fields.

[2] Numbers in parentheses are the number of papers that employ the particular theories and models in designing interventions.

Table 4: Interventions types and corresponding outcomes.

Intervention types	Frequency[1]	BI[2]	BC[2]	K[2]	HI[2]
Diet only	15/33	+1+4/6[3]	+9/11	+2+1/3	+2/6
Diet + Exercise	31/41	+5/9	+7/14		+14/22
Diet + Medical care	3/7	+1/1	+2/2		+1/2
Diet + Exercise + Medical care	1/5				+1/1

[1] The total number of papers having evaluation divided by the total number of papers that include the intervention type.

[2] Change of behavior intention (BI), change of behavior (BC), change of knowledge level (K), and health improvement (HI).

[3] A cell under the BI, BC, K, and HI columns represents the number of studies having positive outcomes divided by the total number of evaluation studies. For example, "+1+4/6" means that there are total 6 papers reporting evaluation studies on dietary interventions. Of the 6 papers, 4 papers report statistically significant positive outcomes, and 1 paper, which number is underlined, reports qualitatively positive outcomes.

11 papers reported significant improvements in behavior changes (+9/11 = 81.8%), but only 2 out of 6 papers reported positive health improvements (+2/6 = 33.3%). In contrast, we noticed that interventions having both diet and physical exercise demonstrated high ratio of positive health improvements (+14/22 = 63.6%) in spite of relatively low ratio of positive behavior changes (+7/14 = 50%).

4.2 Behavior Change Strategies

We organized behavior change strategies and their effects on four outcome measurements as discussed in Section 3.2. In Table 5, we presented the number of papers that used the corresponding strategies and their outcomes using the same format we used for Table 4.

Some strategies were more frequently used (or more popular) than others. Table 5 shows that the most popular strategy is "Provide Instruction;" 62 papers in the paper pool provided educational instruction about nutrition (e.g., Papadaki & Scott, 2005; Carter-Edwards, Bastian, Schultz, Amamoo, & Østbye, 2009), physical activities (e.g., Carter-Edwards et al., 2009), or guidelines (e.g., McConnon, Kirk, & Ransley, 2009; Kitamura, Yamasaki, & Aizawa, 2009). The second popular behavior change strategy is "Provide Feedback on Performance;" 60 papers gave feedback on dietary progress via reports or graphs (e.g., Castelnuovo et al., 2010). The third is "Prompt Self-Monitoring Behav-

Table 5: Behavior change strategies and corresponding outcomes.

Strategies	Frequency[1]	BI[2]	BC[2]	K[2]	HI[2]
Provide Instruction	40/62	+8/11	+16/24	+1+1/2[3]	+11/23
Provide Feedback On Performance	37/60	+7/11	+16/22	+1 /1	+15/24
Prompt Self-Monitoring Behavior	34/58	+1+6/ 9	+12/17		+15/24
Plan Social Support/Social Change	38/57	+1+8/12	+16/22	+1 /1	+17/26
Goal Setting Behavior	30/41	+4/8	+12/18		+13/22
Prompt Self-Monitoring Of Behavioral Outcome	22/33	+4/6	+7/11		+11/16
Barrier Identification/Problem Solving	24/32	+1+6/7	+12/14	+1 /1	+9/16
Reinforcing Effort Toward Behavior	23/32	+4/8	+10/14		+11/16
Action Planning	14/27	+2/5	+5/9	+1 /1	+5/7
Relapse Prevention/Coping Planning	11/16	+1+3/4	+6/7		+5/7
Motivational Interviewing	8/11	+1 /2	+1/5		+4/5
Stress Management	6/10	+1/3	+2/3		+3/4
Provide Rewards For Behavior	6/9	+1/1	+4/5		+2/3
Goal Setting Outcome	4/6		+1/1		+3/3
Provide Information On The Consequences In General	4/5	+1/2	+2/2		
Model/Demonstrate The Behavior	3/5				0/3
Provide Normative Information About Others' Behavior	2/2	+1/1	+1/1		
Agree Behavioral Contract	1/2				0/1
General Communication Skills Training	1/1				+1/1
Provide Information On The Consequences For Individual	0/1				

[1] The total number of papers having evaluation divided by the total number of papers that include the strategy

[2] Change of behavior intention (BI), change of behavior (BC), change of knowledge level (K), and health improvement (HI).

[3] A cell under the BI, BC, K, and HI columns represents the number of papers having positive outcomes divided by the total number of papers having evaluation studies. For example, '+1+1/2' means that there are total 2 papers evaluating an intervention employing the 'Provide Instruction' strategy. Of the 2 papers, 1 paper reports statically significant positive outcomes, and the other 1 paper, which number is underlined, reports qualitatively positive outcomes.

ior;" 58 papers collected dietary intake or physical activities in a diary form (e.g., Tate et al., 2006), 24-hour dietary recall (e.g., Long et al., 2006), or recording voice or pictures via a mobile phone (e.g., Mamykina et al., 2008). 57 papers used"Plan Social Support/Social Change". Participants received dietary aids from professionals (e.g., Gold, Burke, Pintauro, Buzzell, & Harvey-Berino, 2007), peers (e.g., Glasgow et al., 2003), or family (e.g., Eisenmann et al., 2008).

However, these popular behavior change strategies did not necessarily lead to better outcomes. For example, as shown in Table 5, "Provide Instruction" is the most popular strategy in our paper pool, but only 11 papers employing this strategy reported positive results in HI out of 23 evaluation studies (+11/23 = 47.8%). In contrast, if we define more effective strategies as strategies with higher success rates (a ratio between the number of papers reporting statistically significant, positive outcomes and the number of papers including evaluation studies), other strategies appear to be more effective. The most effective strategy is "Relapse Prevention/Coping Planning," which demonstrates its effec-

tiveness on both BC (+6/7 = 85.7%) and HI (+5/7 = 71.4%). For example, Mamykina et al. (2008) evaluated a health monitoring application called MAHI, which provided coping planning for users. Their evaluation results showed statistically significant positive outcomes in both BC and HI measurements. In addition, "Barrier Identification/Problem Solving" is also identified as effective in BC (+12/14 = 85.7%) though it did not demonstrate strong effectiveness in HI (+9/16 = 56.2%). For example, Papadaki and Scott (2008) provided tips on how to overcome barriers in the dietary intervention and reported positive results in promoting more vegetable intakes (one of the behavior change measurements). However, they reported that the level of HDL-cholesterol (one of the health improvement measurements) is not significantly changed. If each outcome measurement is separately considered, some additional behavior change strategies are also noteworthy. In BC, "Provide Feedback On Performance" (+16/22 = 72%) and "Plan Social Support/Social Change" (+16/22 = 72%) are identified as relatively more effective than others. In HI, "Action Planning" (+5/7 = 71%) is relatively more effective in promoting health conditions, as self menu planning (Patrick et al., 2009) and action planning (Funk et al., 2010) techniques demonstrated their effectiveness in improving health conditions.

However, effectiveness should be carefully interpreted because some strategies may appear effective simply because we have only few papers employing these strategies in the paper pool. For example, the paper employing the "Provide Normative Information About Others' Behavior" demonstrated 100% effectiveness in BI (+1/1) and BC (+1/1), but the number of papers that employed and evaluated this strategy was very few. Thus, we only discussed strategies that have been evaluated in more than five papers when we discuss their effectiveness. In addition, readers should note that all web-based interventions in the paper pool employed more than one behavior change strategy. For example, White et al. (2004) employed multiple strategies, such as "Goal Setting Behavior," "Prompt Self-Monitoring Of Behavior," "Prompt Self-Monitoring Of Behavioral Outcome," "Provide Feedback On Performance," "Provide Instruction," and "Plan Social Support/Social Change," based on our analysis. Thus, when they report positive results out of their evaluation study, it is difficult to interpret which of these strategies clearly contributed to the positive results. In other words, effectiveness shown in the BI, BC, K, and HI columns in Table 5 should be interpreted as "the effectiveness of *a certain intervention employing a certain strategy*," rather than "the effectiveness of *a certain strategy*," even though there should be causal relationships. In this paper, we use the phrase, "the effectiveness of *a certain strategy*" for brevity, but this should also be interpreted as the effectiveness of a corresponding intervention,

not the strategy itself.

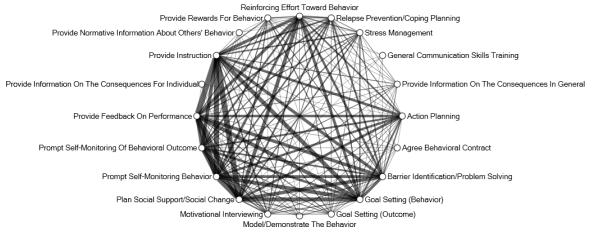
In order to better understand how combinations of multiple strategies are used and which of them are relatively more effective, we drew node-link diagrams of pair-wise combinations. In Figure 1(a), any pairs of strategies employed by a single intervention (or a single paper) are depicted as edges, which we call "co-occurred strategies." The thickness of the corresponding edge represents the frequency of the pair of strategies (see Equation 1). Figure 1(a) shows that almost all of the 20 strategies are comprehensively co-occurred, so that the node-link diagram is almost complete. However, some edges are much thicker than others, showing that the levels of co-occurrences vary. In order to show the most popular combinations more clearly, we filter out combinations with less than 40 co-occurrences and remaining edges are shown in Figure 1(b). If we set a threshold below 40 co-occurrences, the visualization is difficult to interpret because it is overwhelmed by many connections. Therefore, we decided to set 40 co-occurrences as a threshold because the threshold can filter out a major portion of network connections and show only 3.16% of most popular combinations of strategies. Figure 1(b) shows that four strategies ("Provide Instruction," "Plan Social Support/Social Change," "Provide Feedback on Performance," and "Prompt Self-Monitoring Behavior") have been used together more frequently than other combinations. The most co-occurred strategies are a combination of "Provide Instruction" and "Plan Social Support/Social Change," which has co-occurred in 47 papers and is depicted as the thickest edge in Figure 1(b). The next two thickest edges are ones between "Provide Instruction" and "Provide Feedback On Performance" (46 papers), "Prompt Self-Monitoring Behavior" and "Provide Feedback On Performance" (45 papers). Those strategies are also shown in Table 5 as the most popular strategies.

$$RelativeFrequency = \frac{Frequency - min(Frequency)}{max(Frequency) - min(Frequency)} \tag{1}$$

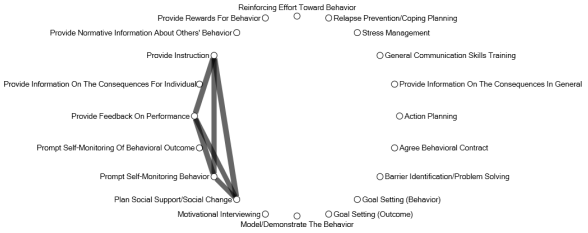
As the most popular strategies are not necessarily the most effective strategies, the most popular combination of strategies, "Provide Instruction" and "Plan Social Support/Social Change," is not the most effective combination. This combination produces a consistently positive effect on BC (+14/19 = 73.7%), but its effectiveness on HI is relatively low (+11/19 = 57.9%). The same trend was found for the four most popular combinations. They demonstrate relatively high effectiveness on BC (all above 70%) but mediocre effectiveness on HI (between 50% and 65%).

The most effective combinations of strategies on both BC and HI are ("Provide Feedback On Performance" and "Plan Social Support/Social Change") and ("Prompt Self-Monitoring Behavior" and "Plan Social Support/Social Change"). Both combinations demonstrate relatively high effectiveness not only on BC (+14/18 = 77.8% and +10/14 = 71.4%, respectively) but also on HI (+14/20 = 70.0% and +15/21 = 71.4%, respectively). However, effective combinations on BC are not necessarily the same as with effective combinations on HI. To show the difference, we plotted Figures 1(c), 1(d), 1(e) and 1(f). Figure 1(c) shows combinations of strategies that demonstrated positive results on BC, and Figure 1(e) shows combinations of strategies that demonstrated positive results on HI. Since these figures could be difficult to understand, we also present figures showing only subsets of the data. We arbitrarily[1] chose 80% and 75% as thresholds to highlight a subset of most effective combinations and to avoid too much clutter in the graph as shown in Figure 1(d) and Figure 1(f). Again, we ruled out the combinations that were evaluated in less than or equal to five papers. This filtering process highlight some of the most effective combinations for BC and HI, which are also listed in Table 6. In Figure 1(d), "Relapse Prevention/Coping Planning" and "Barrier Identification/Problem Solving" appear as central strategies that are connected with five and six strategies, respectively. On the other hand, Figure 1(f) shows that "Reinforcing Effort Toward Behavior" and "Action Planning" are more central, connected to five and three strategies, respectively. Table 6 shows that there are only two combinations, "Barrier Identification/Problem Solving - Reinforcing Effort Toward Behavior" and "Reinforcing Effort Toward Behavior - Relapse Prevention/Coping Planning", appearing in the list of the 11 most effective combinations for BC and HI.

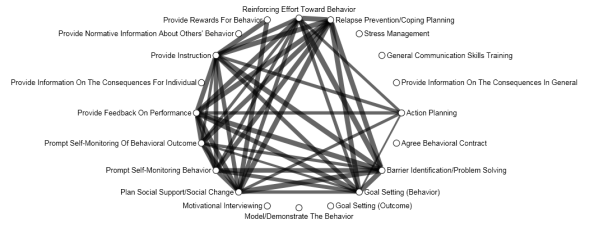
[1]There is no statistical or practical justification for these thresholds, but they are the lowest thresholds that do not cause visual clutter and help identify most effective and well connected strategies.



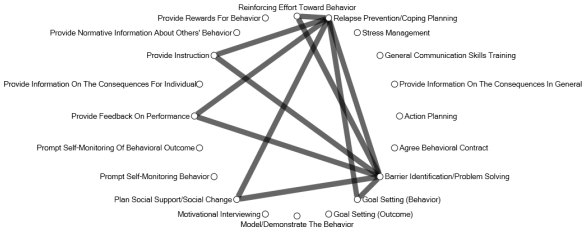
(a) Strategies with any co-occurrences



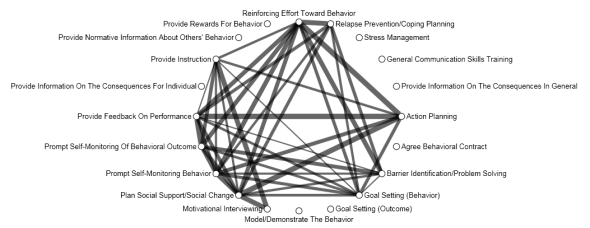
(b) Strategies with 40 or more co-occurrences



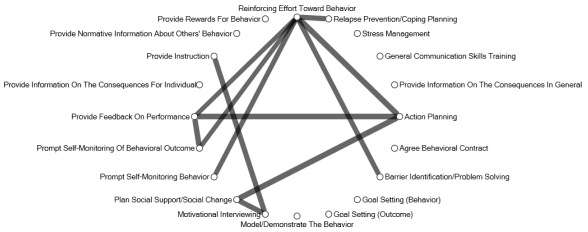
(c) Strategies resulting any positive BC results.



(d) Strategies resulting 80% or more positive BC results.



(e) Strategies resulting any positive HI results.



(f) Strategies resulting 75% or more positive HI results.

Figure 1: Node-link diagram for behavior change strategies combinations. Thickness of edge indicates the relative frequency of co-appearance of two strategies in one paper.

Table 6: Eleven most effective combinations of behavior change strategies and corresponding outcomes.[1]

Behavior Change Strategies Combinations	Frequency[2]	BI[3]	BC[3]	K[3]	HI[3]
Barrier Identification/Problem Solving - Goal Setting (Behavior)	17/28	+3/3	+9/11	0	+7/13
Barrier Identification/Problem Solving - Plan Social Support/Social Change	23/28	+1+6/7[4]	+12/14	+1/1	+9/15
Barrier Identification/Problem Solving - Provide Feedback On Performance	20/27	+5/5	+11/13	+1/1	+8/14
Barrier Identification/Problem Solving - Provide Instruction	18/25	+4/4	+11/13	+1/1	+5/12
Barrier Identification/Problem Solving - Reinforcing Effort Toward Behavior[5]	13/18	+3/3	+7/8	0	+7/9
Barrier Identification/Problem Solving - Relapse Prevention/Coping Planning	8/13	+3/3	+5/6	0	+4/6
Plan Social Support/Social Change - Relapse Prevention/Coping Planning	10/13	+1+3/4	+6/7	0	+4/6
Provide Feedback On Performance - Relapse Prevention/Coping Planning	8/13	+2/2	+5/6	0	+4/6
Provide Instruction - Relapse Prevention/Coping Planning	7/12	+2/2	+5/6	0	+2/4
Reinforcing Effort Toward Behavior - Relapse Prevention/Coping Planning[5]	8/11	+2/2	+5/6	0	+4/5
Action Planning - Plan Social Support/Social Change	11/20	+2/3	+4/7	+1/1	+5/6
Action Planning - Provide Feedback On Performance	11/20	+2/4	+5/8	+1/1	+5/6
Action Planning - Reinforcing Effort Toward Behavior	10/12	+1/3	+4/7	0	+5/6
Barrier Identification/Problem Solving - Reinforcing Effort Toward Behavior[5]	13/18	+3/3	+7/8	0	+7/9
Motivational Interviewing - Plan Social Support/Social Change	7/10	+0/1	+1/5	0	+4/5
Motivational Interviewing - Provide Instruction	7/10	+0/1	+1/5	0	+4/5
Prompt Self-Monitoring Behavior - Reinforcing Effort Toward Behavior	14/20	+2/5	+5/8	0	+10/13
Prompt Self-Monitoring Behavioral Outcome - Provide Feedback On Performance	14/20	+2/2	+6/7	0	+8/9
Prompt Self-Monitoring Behavioral Outcome - Reinforcing Effort Toward Behavior	11/14	+1/3	+4/7	0	+6/8
Provide Feedback On Performance - Reinforcing Effort Toward Behavior	17/24	+2/5	+8/10	0	+9/12
Reinforcing Effort Toward Behavior - Relapse Prevention/Coping Planning[5]	8/11	+2/2	+5/6	0	+4/5

[1] This table shows details of combinations shown in Figures 1(d) and 1(f).

[2] The total number of papers having evaluation divided by the total number of papers that include the combination of strategies

[3] Change of behavior intention (BI), change of behavior (BC), change of knowledge level (K), and health improvement (HI).

[4] A cell under the BI, BC, K, and HI columns represents the number of papers having positive outcomes divided by the total number of papers having evaluation studies. For example, '+1+6/7' means that there are total 7 papers reporting evaluation studies on an intervention employing a combination of "Barrier Identification/Problem Solving" and "Plan Social Support/Social Change" strategies. Of the 7 papers, 6 paper reports statically significant positive outcomes, and the other 1 paper, which number is underlined, reports qualitatively positive outcomes.

[5] Two combinations commonly appear in 11 most effective combinations for BC (top-half) and HI (bottom-half).

4.3 Intervention Media

Our review identifies a wide spectrum of intervention media used for web dietary interventions. As discussed in Section 3.2, we categorize them into 12 types of digital intervention media and 4 types of non-digital intervention media, and the number of papers to contain these types of intervention media are shown in Figure 2 and Table 8. Among 12 categories, we find that "Article/DB/links to information" (e.g., Barrera, Glasgow, Mckay, Boles, & Feil, 2002), "Assessment/graph/report (e.g., Castelnuovo et al., 2010)," and "Discussion/chat room" (e.g., Cussler et al., 2008) are more frequently employed. In Figure 2, bars representing the number of HCI papers are generally shorter than bars for healthcare papers, but the difference is attributed to the fact that the number of HCI papers is much smaller. One interesting pattern noticed is that more HCI papers employed "Camera/phone/voice" intervention media than healthcare papers in spite of the small number of HCI papers. We found that various mobile technologies have been adopted by HCI researchers as a new channel to intervene the target populations, but this trend is less obvious in healthcare papers.

A more interesting discrepancy was found while we compare the level of details in describing their interventions as shown in Table 7. HCI papers tended to describe more about functionalities of their intervention media (22/24 = 91.7%) with visual examples like screenshots (20/24 = 83.3%), but they sometimes missed what kinds of behavior change strategies they intend to deliver (14/24 = 58.3%). In contrast, healthcare papers tended to describe the strategies more (52/62 = 83.9%), but they sometimes omitted the description of intervention media (39/62 = 62.9%) and screen shots (9/62 = 14.5%). Papers in both domains do not provide use cases showing how a potential user uses the intervention media (8/24 = 36.4% for HCI; 1/62 = 1.6% for healthcare).

4.4 Intervention Media and Behavior Change Strategies

Another research question that we would like to answer is "Which intervention media can support which behavior change strategies more effectively?" Answers to this question will help an HCI researcher select proper intervention media according to their behavior change strategies. Table 8 shows relationships between intervention media and behavior change strategies that were identified from our review. While developing this table, we only counted an instance where there is a clear description of how a certain strategy is supported by an intervention medium. For example, when

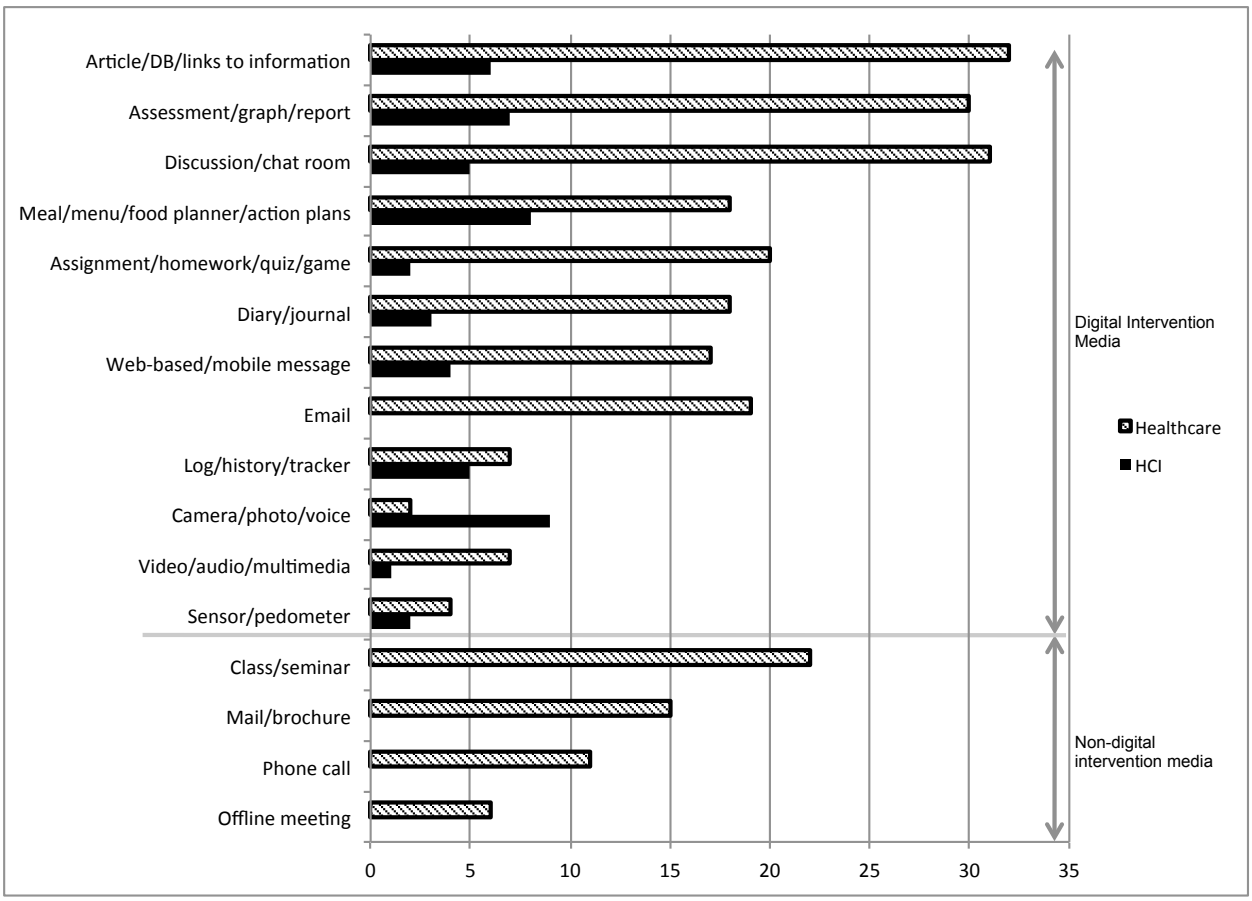


Figure 2: Bar graph showing the numbers of papers that employ intervention media in each category.

Table 7: Levels of descriptions of intervention media in HCI and healthcare papers.

Category	**HCI**	**Healthcare**
Functional description	22/24[1]	39/62
Description of supporting behavior change strategies	14/24	52/62
Use cases	8/24	1/62
Screenshots	20/24	9/62

[1] A cell under the HCI and Healthcare columns represents the number of papers having the contents for corresponding category divided by the total number of papers in the domain (either HCI or healthcare). For example, '22/24' means that there are total 24 HCI papers in our paper pool. Out of the 24 papers, 22 paper have functional descriptions of the intervention media.

we encountered a phrase like "intermittent motivational messages were mailed to participants in an attempt to increase program adherence" (Jones et al., 2008, p. 456), we counted as a case of a "Mail/brochure" intervention medium supporting the "Relapse Prevention/Coping Planning" behavior change strategy. However, in many cases, we could not find such descriptions. Some intervention media were introduced, but it is unclear which strategies that these media support. These cases are labeled as "Uncategorized intervention media" in Table 8. In other cases, papers mentioned that they employed some behavior change strategies, but there were no descriptions of what kinds of intervention media they used to support those strategies even though they mentioned several intervention media were used without clear links to those strategies. Because of this lack of clear links, Table 8 only contains a subset of the comprehensive relationships between intervention media and behavior change strategies. The incomprehensiveness is probably the reason why the seemingly universal 'Email' medium is used in only three papers to support "Provide Instruction," which is also the most popular behavior change strategy. We believe that this table may lead us to a wrong conclusion. As an alternative, we could count a relationship between a medium and a strategy simply when they co-occur in a paper. Table 9 shows the results, but it is also not a perfect way to represent the relationships because it could exaggerate relationships (e.g., there are 17 co-occurrences between "Provide Instruction" and "Diary/journal," though it is difficult to believe that a diary was used to provide instruction). We ended up including both Tables 8 and 9 in this paper because neither of them could provide a perfect summarization of relationships between strategies and media.

However, some interesting patterns emerge. In Table 8, most popular intervention media for each strategy (the maximum value in each row) is bolded. For example, "Provide Feedback on Performance" has been supported by "Assessment/graph/report" (22 papers) (e.g., DeBar et al., 2009); "Prompt Self-Monitoring Behavior" by "Diary/journal" (14 papers); "Plan Social Support/Social Change" by "Discussion/chat room" (31 papers) (e.g., Barrera et al., 2002); "Prompt Self-Monitoring Of Behavioral Outcome" by "Assessment/graph/report" (10 papers); and "Action Planning" by "Meal/menu/food planner/action plan" (21 papers) (e.g., Gold et al., 2007).

However, some of them do not make sense. "Provide Instruction" should be easily done through "Article/DB/links to information," but the most frequently mentioned intervention media is "Class/seminar" (4 papers) for now. Table 9 could partially explain why: 37 co-occurrences between "Providing Instruction" and "Article/DB/links to information" may explain that those technologies are heavily used to "Provide Instruction," but the relationships be-

tween the two may not be explicitly mentioned. Another example would be "Reinforcing Effort Toward Behavior." Though there are 9 papers that clearly mentioned that "Reinforcing Effort Toward Behavior" was supported by "Assignment/homework/quiz/game," 25 co-occurrences might show that it may be better supported by "Discussion/chat room." In addition, there are no clear intervention media that support the most effective strategy, "Relapse Prevention/Coping Planning," which may indicate some future research opportunities.

Table 8: Intervention media used to support behavior change strategies[1].

	DIM[2]												NDIM[2]			
Behavior Change Strategies	Article/DB/links to information	Assessment/graph/report	Discussion/chat room	Meal/menu/food planner/action plans	Assignment/homework/quiz/game	Diary/journal	Web-based/mobile message	Email	Log/history/tracker	Camera/photo/voice	Video/audio/multimedia	Sensor/pedometer	Class/seminar	Mail/brochure	Phone call	Offline meeting
Provide Instruction							1	3			2		**4**			
Provide Feedback On Performance		**22**	1					5						3	2	2
Prompt Self-Monitoring Behavior		5				**14**			6	6		2				
Plan Social Support/Social Change	1		**31**					3								
Goal Setting (Behavior)																
Prompt Self-Monitoring Of Behavioral Outcome		**10**				2	2	1				4			2	
Barrier Identification/Problem Solving	1		2				2				**3**					
Reinforcing Effort Toward Behavior			2		**9**	2	3	8					2	1	5	3
Action Planning				**21**												
Relapse Prevention/Coping Planning														1		
Motivational Interviewing							1	1						1	**4**	
Stress Management																
Provide Rewards For Behavior	**3**															
Goal Setting (Outcome)																
Provide Information On Consequences General																
Model/Demonstrate The Behavior	**1**															
Provide Information About Others' Behavior																
Agree Behavioral Contract																
General Communication Skills Training																
Provide Information On Consequences For Individual																
*Uncategorized intervention media[3]	32			5	13	3	13		6	5	3		16	9		1

[1] Values in the table refer to the number of papers that specifically describe how a intervention media (column) is used to support a behavior change strategy (row). The biggest number in each row is bolded.

[2] Digital intervention media and Non-digital intervention media.

[3] We counted intervention media without description of specific purposes here.

Table 9: Intervention media co-occurred with behavior change strategies[1].

	DIM[2]												NDIM[2]			
Behavior Change Strategies	Article/DB/links to information	Assessment/graph/report	Discussion/chat room	Meal/menu/food planner/action plans	Assignment/homework/quiz/game	Diary/journal	Web-based/mobile message	Email	Log/history/tracker	Camera/photo/voice	Video/audio/multimedia	Sensor/pedometer	Class/seminar	Mail/brochure	Phone call	Offline meeting
Provide Instruction	37	32	35	19	23	17	16	17	10	5	6	5	21	17	10	6
Provide Feedback On Performance	28	33	33	19	20	16	18	18	7	8	6	6	14	14	11	5
Prompt Self-Monitoring Behavior	27	27	31	18	18	19	18	14	10	9	5	6	16	15	10	5
Plan Social Support/Social Change	27	24	37	19	23	15	15	19	10	5	6	7	18	16	9	6
Goal Setting (Behavior)	22	16	26	12	14	11	8	15	6	4	3	3	13	14	7	5
Prompt Self-Monitoring Of Behavioral Outcome	15	14	20	12	11	11	10	10	6	5	2	6	13	6	7	3
Barrier Identification/Problem Solving	19	16	21	9	12	10	12	13	6	4	3	2	9	9	7	3
Reinforcing Effort Toward Behavior	17	9	25	12	15	8	11	16	4	3	4	3	11	9	6	5
Action Planning	11	12	13	22	4	4	8	7	6		3	4	6	2	3	2
Relapse Prevention/Coping Planning	12	5	13	6	5	5	6	7	2	2		1	5	2	3	1
Motivational Interviewing	7	6	8	4	3	5	2	5		1			4	4	4	1
Stress Management	5	4	9		5	5	5	2	1		1		5	4	3	1
Provide Rewards For Behavior	4	3	10	2	6	5		4	1	3	1		4	8	3	
Goal Setting (Outcome)	3	4	6	3	2	5	4	2				1	3		3	1
Provide Information On Consequences General	2	2	3		4	1	3	1	1		2		3	2	1	
Model/Demonstrate The Behavior	4	1	2	3	2				2		1	1	4	3		
Provide Information About Others' Behavior	1	2	2	1	1	1		2					1		1	
Agree Behavioral Contract	2	1	1	1	1		2	2					2			
General Communication Skills Training			1			1		1						1	1	
Provide Information On Consequences For Individual		1	1	1												

[1] Values in the table refer to the number of papers that *simply* contain a intervention media and a behavior change strategy.
[2] Digital intervention media and Non-digital intervention media.

5 Discussion

5.1 Dichotomy Between Healthcare and HCI

Our results clearly demonstrate that healthcare and HCI have different goals in general, which may lead researchers in the two fields to use different evaluation methods, different types of intervention media, and different ways in describing their research. We have found that researchers in healthcare are generally interested in the effects of behavior change strategies on healthcare outcomes, while HCI researchers are more interested in inventing innovative intervention media and supporting technologies.

More specifically, we have found that healthcare papers report their evaluation procedure and outcomes more rigorously and systematically. Studies in healthcare tend to have specific target populations, more frequently relying on controlled evaluation studies for longer periods with more participants. They also employ more specific theoretical models/frameworks and collect more comprehensive healthcare-related measures. However, this does not mean that HCI studies are simply inferior to healthcare studies. Despite a lack of rigor in the evaluation side, HCI studies have diversified and innovated technologies in intervention media, such as multimedia, cameras, and mobile technologies (e.g., Reddy et al., 2007; Nakauchi, Kozakai, Taniguchi, & Fukuda, 2007; Novak et al., 2008), and they generally have more clear descriptions of how their interventions are designed and implemented.

Though it is obvious that two distinct fields have separate directions and methods in their research and practice, it certainly impeded our attempt to build comprehensive and practical guidelines in designing web-based dietary interventions. HCI papers provide innovative ideas for designing and implementing intervention media to promote dietary behavior changes, but they often do not provide enough evidence to show their effectiveness. In contrast, healthcare papers provide detailed descriptions of underlying theories, behavior change strategies, and their evaluation outcomes, but they often rely on simple intervention media or do not provide details of their interventions. This discrepancy between two fields makes it impossible for us to combine evidence and provide a comprehensive discussion.

Furthermore, we believe that this dichotomy may also have impeded collaboration between the two fields. Based on our review, only seven out of 86 papers have co-authors from both fields. The other 79 papers were authored by either HCI researchers or healthcare researchers without interdisciplinary collaborations. We believe that lots

of opportunities are missed here, and there should be bipartisan effort to resolve this issue. Thus, we offer several suggestions for healthcare and HCI researchers in the following subsections.

5.1.1 Suggestions to Healthcare Researchers

As mentioned previously, the omission of descriptions of intervention media became the biggest obstacles for us to construct the comprehensive guidelines. In healthcare papers, the descriptions of used intervention media and actual implementations often remain at an abstract level, as Table 7 shows. Some papers provide URLs for their intervention websites, but many of these websites are not easily accessible (some are out of service; others require complex registration or even a registration fee). Though technical descriptions of used interventions may not be of major interest to the healthcare researchers, we strongly believe that these descriptions are useful not only for HCI researchers but also for anybody who would like to replicate the studies.

There is no single correct way to describe the employed intervention, but we think that the four elements that we used to code the level of descriptions (i.e., the description of intervention media, the explanation of supported behavior change strategies, use cases, and screen shots) would help researchers determine what kinds of elements that they might want to add their papers. In addition, there are several interesting papers that could serve as models: Binks and van Mierlo (2010) report screenshots and descriptions of their website in a series of slides as appendices, which we found appropriate for understanding multiple views of the website. Kroeze et al. (2008) organize the contents of messages and the intention of each message in one table, so that readers can understand what kind of messages were delivered to the target population. McConnon et al. (2009) also use a table to describe features of their website. Lu et al. (2006) reported full details of development process of their dietary consumption tracking system. Beach et al. (2006) explains how a user can use the developed tool in dietary intervention. We believe that these papers provide other researchers with ideas of how to present their intervention media. Also, some of tables introduced in other papers (McConnon et al., 2009; Kroeze et al., 2008) could be directly used as templates. We also discourage the simple provision of URLs to direct readers to their interventions.

5.1.2 Suggestions to HCI Researchers

Conversely, we find that more rigorous evaluation studies as the biggest missing piece in HCI papers while analyzing our paper pool. Though the empirical rigor required in the field of HCI may be lower than that in healthcare, we believe that this difference could be a roadblock for other healthcare researchers relying on HCI research outcomes. Suppose that one healthcare researcher may intend to adopt innovative intervention media to better support their behavior change strategies; it would be challenging for her to assess how effective those innovative intervention media are without comparable evaluation results.

However, adopting those rigorous evaluation methodology often used in the healthcare domain appears to be challenging especially when medical knowledges and equipment are necessary (e.g., blood test). Out of 24 HCI papers, only two papers reported sophisticated healthcare-related measures (Denning et al., 2009; Mamykina et al., 2008), and it is not surprising that both papers have healthcare researchers as co-authors. Thus, collaboration with experienced healthcare researchers would be one of the easiest approaches to achieve the methodological rigor.

We also find several other approaches to make HCI studies more accessible to and viable for by healthcare researchers. First, more theories could be incorporated into designing and evaluating interventions. As shown in Table 3, many healthcare papers adopt social cognitive theory and transtheoretical model to build web-based dietary intervention systems. Winett et al. (1999) would help HCI researchers understand how to follow principles and strategies from social cognitive theory. Second, using taxonomies (Webb et al., 2010; Abraham & Michie, 2008) of behavior change strategies and showing clear links between the strategies and newly developed intervention media would help healthcare researchers understand the intention of a proposed intervention. These two approaches do not require collaborations with healthcare researchers, but adopting the theoretical frameworks and taxonomies from healthcare may make HCI papers more understandable and applicable.

5.2 Notable Patterns

Due to the limitations caused by the dichotomy between the two fields, we failed to provide comprehensive guidelines for designing web-based dietary intervention. However, we noticed several interesting patterns, so we believe that sharing these would be helpful for both HCI and healthcare researchers.

5.2.1 Popular vs. Effective Strategies

The most popular strategies are not necessarily most effective. There were the four most popular strategies ("Provide Instruction," "Provide Feedback On Performance," "Prompt Self-Monitoring Behavior," and "Plan Social Support/Social Change") in the paper pool, but they are not necessarily most effective (see Table 5). These four strategies are also often used together (see Figure 1(b)), but these combinations do not appear most effective either (see Figures 1(d) and 1(f)). In particular, "Providing Instruction" appears to be the most popular strategy probably because instruction should be given for the most of the interventions anyway. However, our results show that it does not guarantee positive behavior changes or health improvement. The other popular strategies ("Provide Feedback On Performance," "Prompt Self-Monitoring Behavior," and "Plan Social Support/Social Change") showed moderate effectiveness in BC and HI, but they do not seem to be popular simply because of their effectiveness. We could not figure out the underlying reasons for their popularity, but one should be aware that using these four strategies does not guarantee improvement of health status in spite of their popularity.

We found that other less popular strategies are more effective. As shown in Figure 1(d), the two strategies ("Relapse Prevention/Coping Planning" and "Barrier Identification/Problem Solving") play central roles in interventions that reported positive behavioral change outcomes. Interestingly, effective strategies in BC do not necessarily lead to successful health outcomes. While "Relapse Prevention/Coping Planning" still remains as one of most effective strategies in HI, the effectiveness of "Barrier Identification/Problem Solving" in HI is not clear. Other strategies, such as "Action Planning" and "Reinforcing Effort Toward Behavior," appear more effective in HI. Figure 1(f) also shows that how these strategies play the central roles in combinations of strategies.

The fact that different strategies are effective depending on healthcare outcomes provide several interesting points. First, they are in line with the Transtheoretical Model (Prochaska & Velicer, 1997). According to the model, behavior changes progress through multiple stages of change. If we need different strategies in different stages of intervention, we may need to dynamically adapt the strategies. The web-based platform has an advantage in this regard because it can provide customized intervention according to each user's status. Second, the fact also unveils the nature of dietary intervention: immediate behavior changes caused by some strategies do not necessarily lead to positive health outcomes because dietary intervention recipients often relapse from time to time in the middle of an interven-

tion (Mamykina et al., 2008; Carpenter, Finley, & Barlow, 2004; Grimes et al., 2008). Thus, sustaining the effort is another aspect of this intervention, so more emphasis should be placed on this aspect in future studies.

5.2.2 Room for Improvements

We also noticed that there are several areas that require more investigation.

First, we noticed that some behavior change strategies are promising, but not much evaluation studies have been done. For examples, "Provide Normative Information About Others' Behavior" are evaluated by two studies (Gold et al., 2007; Kypri & McAnally, 2005), and both of them reported positive outcomes in BI (+1/1) and BC (+1/1). "Goal Setting Outcome" is another promising strategy showing positive outcomes especially in HI (+3/3). These studies are not highlighted in our discussion because we felt that there is insufficient evidence supporting the effectiveness of these strategies. However, more evaluation studies in the future may prove the effectiveness of those strategies.

Second, there are some strategies that are not fully supported by innovative intervention media. For example, we found that only few intervention media are specifically designed to support one of the most effective strategies: "Relapse Prevention/Coping Planning." Only available intervention media that is specifically mentioned to support this strategy is postal mail (e.g., Thompson et al., 2008), and none of the digital intervention media were specifically designed to support this strategy. This could be an interesting research topic for HCI researchers who are focusing on providing innovative intervention media.

Third, we also felt that innovation in HCI should be more appreciated by healthcare researchers. Lots of interesting technologies, such as detecting on-body sensing solutions for automatic dietary monitoring (Amft & Tröster, 2009) and a cell phone based voice memories detailing how they have tried to eat healthfully in their neighborhoods (Grimes et al., 2008). These studies focus on technology development and do not contain rigorous evaluation studies yet. If more healthcare researchers pay attention to those technologies, or the HCI researchers of these technologies can collaborate with other healthcare researchers, the effectiveness of these innovative solutions could be improved.

6 Conclusions

We started this project to create a comprehensive guideline that helps HCI practitioners design a web-based dietary intervention system. We surveyed 86 papers, organized taxonomies of behavior change strategies, intervention media, and health outcomes, and analyzed the relationship between them. After the extensive review, we found a salient dichotomy between healthcare and HCI domains. Healthcare papers have largely focused on behavior change strategies and their impacts on health outcomes, but the descriptions of detailed intervention media are often too abstract or omitted. On the other hand, HCI papers have focused more on technological innovations, but rigorous evaluation studies are largely missing. To close the gap, we suggest both domains to include the full description of technologies and evaluation studies with consistent outcome measurements. We also identified some effective behavior change strategies for web-based dietary intervention, such as "Relapse Prevention/Coping Planning," "Barrier Identification/Problem Solving," "Reinforcing Effort Toward Behavior," "Action Plan," and their combinations. However, we need to investigate which intervention media could maximize the benefit of those behavior change strategies. We hope that these preliminary findings provide an opportunity for both HCI and healthcare researchers to become aware of the dichotomy between the two fields and promote more collaborations to close the gap.

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