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Exploring the Relationship Between Intrinsic Motivation and Receptivity to mHealth Interventions

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Abstract

Recent research in mHealth has shown the promise of Just-in-Time Adaptive Interventions (JITAIs). JITAIs aim to deliver the right type and amount of support at the right time. Choosing the right delivery time involves determining a user's *state of receptivity,* that is, the degree to which a user is willing to accept, process, and use the intervention provided.

Although past work on generic phone notifications has found evidence that users are more likely to respond to notifications with content they view as useful, there is no existing research on whether users' intrinsic motivation for the underlying topic of mHealth interventions affects their receptivity. In this work, we explore whether relationships exist between intrinsic motivation and receptivity across topics and within topics for mHealth interventions. To this end, we conducted a study with 20 participants over 3 weeks, where participants received interventions about mental health, COVID-19, physical activity, and diet & nutrition. The interventions were delivered by the chatbot-based iOS app called Elena+, and via the MobileCoach platform.

Our exploratory analysis found that significant differences in mean intrinsic motivation scores across topics were not associated with differences in mean receptivity metrics across topics. We also found that positive relationships exist between intrinsic motivation measures and receptivity for interventions about a topic.

1 Introduction

The ubiquity of smartphones and wearables, coupled with advances in built-in sensor technology, has led to a wide array of research opportunities and applications for mobile health (mHealth). mHealth aims to use mobile and wireless technologies to deliver effective interventions that improve health outcomes. Researchers have designed various smartphone-based interventions to promote outcomes such as reducing smoking, increasing physical activity, eating healthier, and improving mental health [31, 12, 22, 3].

Recent mHealth studies have used Just-In-Time Adaptive Interventions (JITAIs) to promote positive behavioral changes. JITAIs provide the right type and amount of support, at the right time, depending on the individual's changing internal and contextual state [17]. For JITAIs to be delivered at the correct time, a person must receive an intervention when entering a state of vulnerability or opportunity, and when in a state of receptivity.

Recipients are in a *state of vulnerability* when they are susceptible to negative health outcomes, such as someone suffering from an alcohol disorder experiencing an alcohol craving [17]. Designers of JITAIs can use Ecological Momentary Assessments (EMAs) and sensor data to determine when someone enters a state of vulnerability. For example, a mood assessment or GPS coordinates approaching a location associated with past alcohol abuse can indicate an alcohol craving. Conversely, recipients are in a *state of opportunity*

when they are susceptible to positive health behavior changes. SitCoach is a JITAI that identifies 30 minutes of uninterrupted computer time as a teachable moment to inform a worker about his/her sedentarism. After detecting this state of opportunity, SitCoach delivers messages encouraging the worker to be more active [35]. The design of JITAIs assumes that a recipient will be more likely to interact with – and benefit from – interventions delivered during a state of vulnerability or opportunity [17].

Determining the right time to deliver a JITAI also involves discerning an individual's *state of receptivity,* which is a person's ability to receive, process, and use the intervention support [17]. For example, if a person ignores an intervention prompt, he/she is not receptive. Receptivity may be determined by intrinsic factors such as age and personality, and contextual factors such as a person's location, current activity, or stress level [12]. Delivering support when a person is not receptive could possibly reduce a person's motivation to continue engaging with the intervention, by adding to a person's intervention fatigue. Several studies have shown that individuals use mHealth resources only a few times before abandoning them, decreasing the effectiveness of such interventions [10]. Providing support when a recipient is receptive may decrease intervention fatigue and increase intervention engagement, resulting in improved adherence to mHealth interventions [17].

Previous research on generic phone notifications has demonstrated the relationship between individuals' perceptions of notification content and receptivity. People tend to be more receptive towards notifications with content they view as important, urgent, or useful [16]. When people choose whether to process a notification, the content of the notification can outweigh the timing of the notification as a deciding factor [7]. Modeling an individual's past interest with notification content can improve the precision of predicting the engagement rate of notifications [20].

There is little existing research on whether an individual's intrinsic motivation towards the content of mHealth interventions affects receptivity, however. *Intrinsic motivation*, the most autonomous form of motivation, involves doing an activity for the inherent satisfaction of the activity itself. Intrinsic motivation and greater internalization of behavioral goals has been associated with better retention and behavioral health outcomes including greater adherence to medications [36], better long-term maintenance of weight loss among obese patients [37], improved glucose control among diabetics [36], and greater attendance in an alcohol addiction treatment program [30].

In the work reported herein, we study whether there are relationships between intrinsic motivation and receptivity for mHealth interventions about various topics. We explore variation in intrinsic motivation across topics, looking at whether individuals who express higher intrinsic motivation for a certain health topic on average have greater receptivity for digital interventions about that topic compared to other topics. Additionally, we will study within-topic variation in intrinsic motivation, to determine whether individuals who express high intrinsic motivation for a topic on average have greater receptivity compared to individuals who express low intrinsic motivation for that topic.

If either across-topic or within-topic relationships exist between intrinsic motivation and receptivity, designers of JITAIs could tailor intervention content to support the psychological needs that enhance intrinsic motivation. According to the self-determination theory, social and contextual factors that support the three innate psychological needs of autonomy, competence, and relatedness can promote intrinsic motivation and well-being [27]. Goal-setting [13] and motivational interviewing [24] can be incorporated into interventions to increase intrinsic motivation and internalization of behavior [14].

We conducted a 21-day study in which participating volunteers received three digital coaching interventions a day, delivered at random times within a morning, afternoon, and evening time interval. The interventions were delivered using an app and mobile system designed to detect moments of receptivity [12]. We grouped the coaching sessions into four intervention topics, including mental health, COVID-19, physical activity, and diet & nutrition. On a weekly basis, we surveyed participants with an Intrinsic Motivation Inventory containing the subscales of interest/enjoyment, perceived competence, perceived choice, and value/usefulness for each intervention topic. We then analyzed participants' receptivity to interven-

tion initiating messages to explore the relationships between intrinsic motivation and receptivity to mHealth interventions.

The metrics for evaluating participants' receptivity to intervention messages include (1) overall response rate, i.e., the fraction of initiating messages a participant read and responded to, (2) just-in-time response rate, i.e., the fraction of initiating messages a participant read and responded to within ten minutes of delivery, (3) conversation rate, i.e., the fraction of interventions a participant fully engaged in and completed, and (4) response delay, i.e., the length of time between when the message was sent and when the participant responded [12]. We formulate the following hypotheses:

- H1: When a participant has a higher intrinsic motivation score for an intervention topic, the participant's average overall response rate to messages about that topic will be higher than for other topics.
- H2: When a participant has a higher intrinsic motivation score for an intervention topic, the participant's average response delay for interventions about that topic will be lower than for other topics.
- H3: The higher a participant's intrinsic motivation score for a topic, the higher the likelihood that the participant responds to messages for that topic.
- H4: The higher a participant's intrinsic motivation score for a topic, the lower the response delay for interventions about that topic.

2 Background

In this section, we discuss the Self-Determination Theory, which defines intrinsic motivation and the social contextual factors that support it. We then describe the Intrinsic Motivation Inventory, a survey used in health studies to measure participants' level of intrinsic motivation. Finally, we define the metrics used in our study to measure an individual's state of receptivity.

2.1 Self-Determination Theory

Self-Determination Theory (SDT) is a broad framework for understanding human motivation and personality [27]. SDT defines intrinsic motivation as doing an activity for the inherent satisfaction of the activity itself, while extrinsic motivation involves performing an activity to attain some separable outcome [27]. As an organismic theory, SDT assumes people are inherently intrinsically motivated, meaning they naturally strive to learn, master new skills, and develop their sense of self [27].

These proactive tendencies are not automatic. SDT argues that individuals must satisfy three innate psychological needs – autonomy, competence, and relatedness – to enhance self-motivation and well-being [27]. Autonomy involves having an internal perceived locus of causality, the idea that one's behavior is self-determined. Competence refers to the feeling of mastery, the belief that one can develop and succeed. Relatedness entails feeling a sense of connection to others and belonging to a social group [28]. Thwarting any of these three psychological needs can hinder self-motivation, social functioning, and personal well-being [27].

Cognitive Evaluation Theory (CET) is a subtheory within SDT that interprets results from laboratory experiments testing whether external rewards affect intrinsic motivation [27, 8]. The principles of CET only apply to activities that individuals are intrinsically motivated to perform, such as activities that hold some intrinsic interest or appeal. CET suggests that social environments can increase or decrease intrinsic motivation by supporting or thwarting people's basic psychological needs [27]. Extrinsic rewards or pressure that contribute to an external perceived locus of causality diminish intrinsic motivation [4]. In contrast,

opportunities for choice and self-direction that increase the feeling of autonomy were found to enhance intrinsic motivation [4]. Additionally, feedback and rewards that contribute towards feelings of competence during an action enhance intrinsic motivation for that action, while negative performance feedback diminishes it [4]. In studies of infants [9] and students [1], participants exhibited greater intrinsic motivation in contexts characterized by a sense of security and relatedness, compared to contexts where the participant is ignored.

A subtheory within SDT, organismic integration theory (OIT), describes the different forms of extrinsic motivation as falling along a continuum of self-determination, the degree that motivation emanates from the self [27]. The self-determination continuum increases from left to right, with amotivation on the far left, followed by four forms of extrinsic motivation, and intrinsic motivation on the far right [27]. When people are in a state of amotivation, they either do not act at all or act without intent. Amotivation stems from not valuing an activity, not feeling competent to perform it, or not expecting the activity to yield a desired result [27]. Intrinsic motivation involves people performing an activity because of interest and enjoyment, unlike actions characterized by extrinsic motivation that are performed because of a perceived sense of value [28].

The least autonomous form of extrinsic motivation, *external regulation*, concerns behaviors driven by external rewards and punishments. Individuals experiencing externally regulated behavior typically interpret their actions as having an external perceived locus of causality [27]. *Introjected regulation* describes extrinsic motivation that has been partially internalized but not integrated. *Internalization* refers to "taking in" a value or regulation of behavior. *Integration* further transforms that regulation into part of one's sense of self. So introjection involves taking in a regulation but not fully accepting it as part of one's self [27]. In this stage, behavior is regulated by the internal rewards of self-esteem for success and avoidance of anxiety or guilt for failure. In *identified regulation*, the person consciously values a behavioral regulation, and accepts the activity as personally important. In the most autonomous form of extrinsic motivation, *integrated regulation*, the person identifies with the value of the activity and brings it into alignment with one's other core interests and values. [28]. While actions characterized by integrated regulation share similarities with intrinsic motivation, integrated regulation is still considered extrinsic because such actions are performed to attain separable outcomes, and not out of pure enjoyment [28].

2.2 Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) is a multidimensional measure of participants' subject experience toward a particular activity, developed by Ryan and his colleagues [25, 26, 21]. The IMI determines participants' level of intrinsic motivation by adding together the scores of up to seven possible subscales: interest/enjoyment, perceived competence, effort/importance, pressure/tension, perceived choice, value/usefulness, and relatedness [23].

The interest/enjoyment subscale is considered the self-report measure of intrinsic motivation. The perceived choice and perceived competence subscales are theorized to be positive predictors of the self-report of intrinsic motivation, and are related to the SDT psychological needs of autonomy and competence [23]. Pressure/tension is theorized to be a negative predictor, as pressure or tension experienced while performing an activity can detract from enjoyment [23]. The effort/importance subscale measures the amount of effort participants spend on an activity, and the extent to which they found it worthwhile [21]. The value/usefulness subscale has been used in internalization studies, as SDT argues that people internalize and self-regulate activities they experience as useful or valuable to themselves [23].

Each subscale has five to seven statements, which individuals must rate using a Likert scale from 1 (not at all true), through 4 (somewhat true), to 7 (very true). The score for each subscale is the average rating for the statements in the subscale. For negatively worded statements [23], the rating is replaced by 8 minus the rating; thus, a scale of 1..7 on a negatively worded statement becomes a scale of 7..1, so a larger numeric

rating always represents a more-positive response.

Past research has found negligible effects from changing the order of survey items, and from including or excluding various subscales [5]. As a result, experimenters rarely use all items and instead pick the subscales relevant to their research questions [5]. Different versions of the IMI have been used and validated in various contexts including sports, education, and schizophrenia [5, 34, 2].

2.3 Receptivity Metrics

We use the following metrics for capturing the *state-of-receptivity* of an individual as defined by Künzler and Mishra, et al. [12]. The metrics are divided into two categories, metrics that capture the receptivity of a person *in-the-moment* and metrics that capture the receptivity of a person over an extended period of time.

2.3.1 Metrics for in-the-moment receptivity

Paraphrasing from Künzler and Mishra, et al. [12]:

- *Just-in-time response*: If the user views and replies to an initiating message within 10 minutes, we conclude the user was in a receptive state at the time of the intervention message delivery. The *just-in-time response* for that initiating message is set to true.
- *Response*: If the user responds to the initiating message at any time in the morning, afternoon, or evening interval in which it was delivered, the *response* for that initiating message is set to true.
- *Response delay*: The time in minutes between receiving an intervention based message (the initiating message delivered as a notification) and replying to it. If the initiating message was delivered at time t and the participant replied at time t', then the *response delay* is $t' - t$.
- *Conversation engagement*: We define a participant as engaged in conversation with the chatbot if the participant completed the intervention following the initiating message. If the participant received the final intervention message before the end of the interval in which the initiating message was delivered, then the *conversation engagement* is set to true.

2.3.2 Metrics for receptivity over an extended period of time

Paraphrasing from Künzler and Mishra, et al. [12]:

- *Just-in-time response rate*: The fraction of initiating messages for which the participant had a *just-in-time response* to over a given period.
- *Overall response rate*: The fraction of initiating messages a participant responded to (*just-in-time* or not) over a given period.
- *Conversation rate*: The fraction of initiating messages for which the participant engaged in a conversation, over a given period.
- *Average response delay*: The mean response delay, over a given period.

3 Related work

In this section, we look at related work about the application of self-determination theory to health care contexts.

3.1 Self-Determination Theory in Health Care

One of the greatest opportunities to improve population health and reduce premature deaths involves behavioral change [32]. Potentially controllable behaviors related to smoking, hygiene, diet, and physical activity can greatly affect people's health [29]. Additionally, the effectiveness of most health-care interventions depend on patients adhering to behaviors such as taking medications, performing self-examinations, and correcting habits [29].

Self-determination theory describes the processes through which a patient acquires the motivation to initiate new health behaviors and maintain them over time [29]. SDT argues that the processes of internalization and integration are essential to self regulating and sustaining healthy behaviors [29]. *Internalization* involves "taking in" the values of a behavior, while *integration* means bringing those values into alignment with one's own values and sense of self [27]. Internalization and integration depend on the satisfaction of the psychological needs of autonomy, competence, and relatedness [27]. Thus, SDT predicts treatment environments that support patient autonomy, competence, and relatedness yield enhanced adherence and health outcomes [29]. An autonomy supportive environment provides opportunity for choice, information about the problem, acknowledgement of patient emotions, and minimizes pressure for the patient to behave in a certain way [36].

Researchers have applied SDT to health-care contexts to study whether autonomous motivation and satisfaction of psychological needs is correlated with behavior change and positive health outcomes [18]. Autonomous motivation and perceived physicians' autonomy support has been found to be strongly associated with patients' adherence to long-term prescriptions [38]. Perceptions of providers as autonomy supportive successfully predicted improved maintenance of blood-glucose regulation by diabetes patients [38]. The perception of health-care staff as need-supportive had a significant correlation with autonomous reasons for engaging in exercise one year after the intervention ended, finding that internalization can influence long-term behavior [33]. In this same study, autonomous motivation was also correlated with a reduction in body weight, showing an improvement in health outcomes [33].

A meta-analytic review of 184 SDT based studies in health care observed moderate effects of autonomy-supportive health-care climates, basic needs satisfaction, and autonomous self regulation on various indicators of mental and physical health [18]. The overall pattern of these effects supported SDT, with autonomy-supportive health care positively predicting higher levels of patient autonomy, competence, and relatedness for that health behavior domain. The three psychological needs predicted moderate to strong levels of patient welfare. A few studies followed patients for up to 24 months after interventions ended, and found evidence of long-term positive health outcomes [18].

4 Methods

In this section, we discuss our study goals and design, the smartphone app used to deliver interventions (Elena+), the study description, and the IMI we constructed. We then describe the data collected during the study, and our approach to data analysis.

4.1 Study Design

To deliver our interventions, we deployed a modified version of the Elena+ iOS app [19]. The Elena+ iOS app is based on the MobileCoach platform, developed by Filler et al. [6, 11]. Elena+ is a chatbot-based digital coach that delivers 43 different educational interventions on 7 topics: COVID-19, physical activity, diet and nutrition, sleep, anxiety, mental resources, and loneliness. For more details on the Elena+ Coaching Session topics, see Appendix Figure 40.

At the end of each intervention, the digital coach asks the user to set goals to promote physical or mental health. The original Elena+ app allows users to complete these interventions at their own pace over a period of two months.

We modified the app so that users received a generic initiating push notification three times a day, at a random time within a morning, afternoon, and evening interval. The intervals were from 8 am to 11 am, 1 pm to 4 pm, and 6 pm to 9 pm EDT. The initiating push notification told the user it was time for a coaching session, but did not specify the topic of the intervention. See Appendix Figure 41 for an example push notification. The digital coach always delivered an intervention in a topic different from the topic in the previous interval.

The interventions in our study were chat-based conversational messages from the digital coach, with some messages requiring participants to answer by selecting from pre-defined answer options. We defined the first message requiring a participant answer to be the *initiating message* of the conversation. Metrics for response, just-in-time response, and response delay were calculated based on participants' response times to initiating messages. See Appendix Figure 42 for an example initiating message.

If a user did not complete an intervention an hour before the next interval, we sent a push notification reminding them to complete the coaching session. Reminder notifications were sent at 12 pm, 5 pm, and 10 pm EDT. If the user still did not complete the session by the time the next interval began, it was delivered again within the next week. With these modifications, we estimated users would complete all 43 interventions over 15-21 days. The Elena+ app logged information about all messages sent to users. If Elena+ logged that a participant received the last message of an intervention, we set the participant's conversation engagement to true for that intervention.

We also modified the Elena+ app to collect smartphone sensor data, which was used to determine the context of the user. The sensor data included GPS location, physical activity, date and time, proximity to the phone, Wi-Fi connection status, the name and MAC addresses of nearby Bluetooth devices, ambient-light level, battery percentage and charging status, whether the screen was on or off, noise levels and whether the user was in conversation, daily call and SMS logs, the type of application used in the foreground, and a hash of the foreground application name.

In addition to the Elena+ iOS app, participants were required to install an app on their Macbook laptop to collect data about the participant's interaction with their laptop. The laptop app collected CPU/RAM Usage, mouse clicks, mouse movement, mouse scroll events, and keyboard key-presses. The laptop app included an accompanying browser plug-in that collected data on tab changes, the type of website open, and a hash of the website name.

Participants were asked to keep both the iOS and laptop apps running throughout the duration of the study. For each participant, the monitoring lasted at most 21 days, the estimated amount of time for users to complete all interventions. Monitoring ended earlier if a participant completed all interventions before the 21st day. Participants no longer received any new messages and were instructed to uninstall the applications from their iPhone and Macbook. They also received an email message with a link to the post-study usability survey, which contains questions about perceived disruptions from the notifications and the timing of message prompts. Upon completion of the survey, we sent the participants a USD$40 Amazon gift card, regardless of how many interventions they completed.

At the start of the study, participants were told that the Elena+ app is used to promote positive lifestyle outcomes during the pandemic. We also explained to participants that we were collecting various sensor data from their iPhone and laptop to determine the effectiveness of the interventions. However, the true purpose of the study was to understand how a participant's intrinsic motivation relates with receptivity to digital health interventions. The sensor data was collected to determine how context influences receptivity.

The study's main variable of interest was *receptivity:* how participants responded to and interacted with intervention messages. To avoid skewing the results, we did not tell participants our intention to observe how quickly they reacted to messages, as they might have reacted differently knowing they were observed.

Participants were instructed to treat the Elena+ app as any other app on their iPhone. We did not ask participants to respond to initiating push notifications or to complete the interventions.

Since this study was concerned with how intrinsic motivation relates to receptivity, we designed the study compensation to avoid motivating participants to react to interventions. At the start of the study, we informed participants that they would be compensated with an Amazon gift card for participation in the study. The consent form states that "participation includes completing the pre-study survey, installing the app, interacting with the app for three weeks, and completing the post-study survey." To ensure that this would not serve as an extrinsic reward for reacting to interventions, we did not specify what 'interacting' with the app entails, and did not require participants to complete a certain number of interventions.

4.2 Enrollment and Data Collection

We advertised the study through emails, Facebook, and IRB-approved flyers placed around the Dartmouth College campus. Thirty-eight college students filled out the consent form; eight did not meet the eligibility criteria (living in the Eastern time zone and owning an iPhone and Macbook). Five participants withdrew from the study before installing the iOS and laptop apps. Ultimately, 20 participants completed the study. Of the 20 participants, 13 were female and 7 were male. The median age of participants was 20.5 years.

After consenting to the study via the consent form, participants completed a pre-study questionnaire including a brief demographic survey, BFI-10 personality survey, Perceived Stress Scale survey, questions on interest and perceived competence for the seven coaching topics, and an Intrinsic Motivation Inventory for each of following the categories: COVID-19 guidelines, physical activity, diet and nutrition, and mental health. To reduce respondent burden, we asked participants to fill out an IMI for each of these four topics instead of the seven Elena+ coaching session topics described in Appendix Figure 40.

At the end of every week in the study, we asked participants to complete the four Intrinsic Motivation Inventory surveys based on their current motivational state. We also asked participants to rate their interest on a scale of 1 (not at all interested) to 5 (extremely interested) and their confidence in their ability to improve on a scale from 1 (not at all confident) to 5 (completely confident) for each of the seven coaching topics. Participants completed the four IMIs and interest and confidence questions for the coaching topics a total of four times: the pre-study questionnaire, the end of week 1, the end of week 2, and the post-study usability survey. Summary statistics about participant interaction with initating messages are presented in Table 1.

Table 1: Study Stats: Initiating messages are the first messages in the coaching session that require a participant reply, initial responses are the responses to the initiating messages, just-in-time response % is the same as just-in-time response rate from Section 2.3.2, conversations engaged % is the same as conversation rate from Section 2.3.2, averaged across all participants.

	Total	Percentage
Initiating Messages	1236	
Initial Responses	373	30.18%
Just-in-time Responses	96	7.77%
Conversations Engaged	207	16.75%

4.3 Our Version of the Intrinsic Motivation Inventory

In our experiment, we constructed an IMI using four subscales: interest/enjoyment, perceived competence, value/usefulness, and perceived choice. We included the interest/enjoyment subscale as it is considered a self-report of intrinsic motivation. Perceived choice and perceived competence are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation [23]. We chose the value/usefulness subscale because people tend to be more receptive towards notifications with content they view as important, urgent, or useful [16], and because people internalize motivation for activities they perceive as having value [27]. Our aim is to determine whether receptivity or engagement is correlated with any of these subscale measurements of intrinsic motivation, and whether these measures change over time. Using these four subscales results in a 24-item version of the IMI.

For each intervention topic, we altered the IMI items to focus on the health goal promoted by Elena+ interventions for that topic. For example, the mental health IMI focused on "working on improving mental health," while the IMI for COVID-19 focused on "following COVID-19 guidelines." The specific items used in each IMI are shown in Appendix Tables 13, 14, 15, and 16.

To test the internal consistency reliability of our constructed IMIs, we calculated the Cronbach's alpha coefficient for the total IMI and subscales for each topic. The internal consistency measures for the total IMIs were high. As shown in Table 2, mental health had $\alpha = 0.83$, COVID-19 had $\alpha = 0.81$, physical activity had $\alpha = 0.94$, and diet & nutrition had $\alpha = 0.94$. The internal consistency of the subscales were generally good, as interest/enjoyment and perceived competence, and value/usefulness had $\alpha > 0.80$. Perceived choice had $\alpha < 0.70$, ranging from questionable reliability for mental health, COVID-19, and physical activity to poor reliability for diet & nutrition.

Table 2: Cronbach's alpha coefficient (α) for the total IMI score and IMI subscale scores for each topic

Topic	Total	Interest/ Enjoyment	Perceived Choice	Perceived Competence	Value/ Usefulness
Mental Health	0.83	0.83	0.60	0.90	0.96
COVID-19	0.81	0.83	0.62	0.86	0.94
Physical Activity	0.94	0.94	0.63	0.88	0.97
Diet & Nutrition	0.94	0.94	0.55	0.93	0.97

4.4 Data Analysis

In our analysis, we explored how intrinsic motivation inventory scores relate to receptivity towards mHealth interventions both across-topics and within-topics.

To prepare for this analysis, we divided the 43 digital coach initiating messages into the four topics used for the IMI surveys. COVID-19, physical activity, and diet & nutrition contained the messages from the similarly named Elena+ coaching session topics. Mental health included messages from the Elena+ coaching session topics of mental resources, sleep, anxiety, and loneliness. As a result, the mental health topic included a little over half the total number of initiating messages, as shown in Table 3.

We formed two plans for data analysis, one procedure to answer H1 and H2 about intrinsic motivation score variation across topics, and another to answer H3 and H4 about intrinsic motivation score varition within topics. Formulated in Section 1, H1 and H2 predicted that a participant with a higher intrinsic motivation score for a certain topic would have greater receptivity to initiating messages about that topic compared to initiating messages about other topics. H1 specified greater receptivity as a higher average

Table 3: Division of Initiating Messages into Intervention Topics: Mental health contained initiating messages from Elena+ coaching sessions on mental resources, sleep, anxiety, and loneliness. COVID-19 contained initiating messages from COVID-19 coaching sessions. Physical activity contained initiating messages from physical activity coaching sessions. Diet & nutrition contained initiating messages from diet & nutrition coaching sessions.

Intervention Topic	Number of Initiating Messages	Percentage of Total
Mental Health	22	51.16%
COVID-19	10	23.26%
Physical Activity	8	18.6%
Diet & Nutrition	3	6.98%

overall response rate, while H2 specified greater receptivity as a lower average response delay. To answer H1 and H2, we created linear mixed effects models that compared the differences in mean receptivity over a given time period for the four topics. The metrics for receptivity over a given time period evaluated in our analysis included overall response rate, just-in-time response rate, conversation rate, and average response delay. We also created linear mixed effects models to compare the differences in the mean total IMI score and each IMI subscale score for the four topics. For our post-hoc analysis, we ran Tukey's honestly significant difference (HSD) tests for each linear mixed effects model to find the statistical significance of the pairwise comparisons.

H3 and H4 predicted that within a single topic, higher intrinsic motivation scores would be associated with greater receptivity towards initiating messages for that intervention topic. H3 specified greater receptivity as higher likelihood of response, while H4 specified greater receptivity as lower response delay. To answer H3 and H4, we constructed linear mixed effects models and generalized linear mixed effects models to calculate how different receptivity metrics in-the-moment and over a given time period varied with IMI subscale scores.

To construct receptivity metrics over a given time period, we had to define the time periods for each participant. During the study, participants took an IMI survey for each of the four topics a total of four times: during the pre-study questionnaire, end of week one survey, end of week two survey, and the post-study usability survey. Ideally, participants would have completed the IMI surveys on the days they were sent, days 0, 7, 14, and 21 of the study. However some participants completed the survey a few days after it was sent to them.

Our initial analysis set a time period as the number of days in-between two consecutive survey completion dates, generally around a week. For the ideal example with surveys completed on days 0, 7, 14, and 21, the pre-study IMI scores applied to days 0-6, the end of week one IMI scores applied to days 7-13, and the end of week two IMI scores applied to days 14-21. One drawback of this method of defining time periods was that the IMI scores collected in the post-study usability survey were not incorporated into the analysis.

We then devised a partial interpolation method to include all four sets of IMI scores into our analysis. We found the halfway points in between survey completion dates, and set the time period to be the number of days between these halfway points. For the example of surveys completed on days 0, 7, 14, and 21, the pre-study IMI scores applied to days 0-3, the end of week one IMI scores applied to days 4-10, the end of week two IMI scores applied to days 11-17, and the post-study usability survey IMI scores applied to days 18-21.

The metrics for receptivity over an extended period of time were then calculated over the time periods

set using the second method. For example, if a time period for a participant contained days 0-3, the response rate for that time period was the fraction of initiating messages that the participant responded to during days 0-3 of the study.

5 Results

In this section, we present the results of our data analysis, and evaluate whether the results support or failed to support our hypotheses defined in Section 1.

First we show our results for the analysis performed to answer H1 and H2. This across-topics analysis determined whether a higher mean intrinsic motivation score for a topic was associated with greater mean receptivity for that topic compared to others. We then present our results for the analysis conducted to answer H3 and H4. For this within-topic analysis, we evaluated whether a higher intrinsic motivation score was associated with greater receptivity for interventions about that topic.

5.1 H1 and H2 – Exploring Whether a Relationship Exists Between Mean Intrinsic Motivation and Mean Receptivity Over a Given Time Period Across Topics

For the following analysis across intervention topics, we used linear fixed effects models to compare differences in mean receptivity across topics to the differences in mean IMI total score and subscale score across topics. We then conducted Tukey's HSD tests to find the significance of these pairwise comparisons. We evaluated metrics for receptivity over a given time period, including overall response rate, just-in-time response rate, conversation rate, and average response delay.

5.1.1 Overall Response Rate

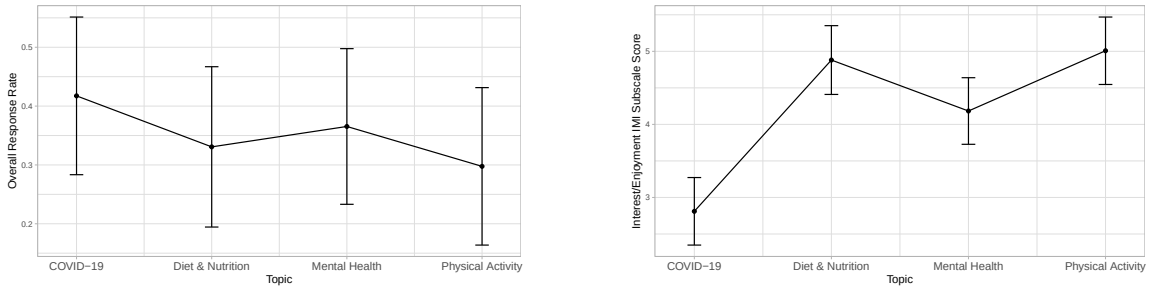
We defined the overall response rate as the fraction of initiating messages a participant responded to over a given time period.

We began our overall response rate analysis by constructing a linear mixed effects model where the response variable was the overall response rate, and the fixed effect was the intervention topic. There were 20 groups, for the number of participants who completed the study. Figure 1a plots four points representing the mean overall response rate for each intervention topic. The whiskers show the 95% confidence interval for the mean overall response rate. The line connecting the four points does not represent any data, and was included for easier comparison with Figure 1b.

Figure 1b was created from a linear mixed effects model where the response variable was set to the interest/enjoyment subscale score, and the fixed effect was set to the intervention topic. There were 20 groups, for the number of participants who completed the study. Figure 1b plots four points representing the mean interest/enjoyment subscale score for each intervention topic. Similar to Figure 1a, the whiskers show the 95% confidence interval, and the line connecting the four points does not represent any data points.

As evident in Figure 1b, the topics with the highest mean interest/enjoyment score were diet & nutrition and physical activity. However in Figure 1a, the mean overall response rates for diet & nutrition and physical activity were lower than the mean overall response rate for other topics. Conversely, COVID-19 had the lowest mean interest/enjoyment score among the topics, but had the highest mean overall response rate. These results did not support H1, that higher average interest/enjoyment subscale scores for a topic should correspond to higher average overall response rate for that topic compared to others.

For our post-hoc analysis, we ran a Tukey HSD test on the overall response rate linear mixed effects model to determine whether the differences between mean overall response rates were significant. As shown in Table 4, there were no significant differences in mean overall response rates between topic pairs.



(a) Overall Response Rate by Topic

(b) Interest/Enjoyment Score by Topic

Figure 1: Comparing variation in overall response rate to variation in interest/enjoyment scores across topics

We also ran a Tukey HSD test on the interest/enjoyment linear mixed effects model to test whether the differences between the mean interest/enjoyment subscale scores were significant. As shown in Table 5, the difference in mean interest/enjoyment subscale scores for pairwise comparisons COVID-19 – diet & nutrition, COVID-19 – mental health, and COVID-19 – physical activity were all significant at $p < .0001$. The pairwise differences for diet & nutrition – mental health and mental health – physical activity were significant at $p < .01$.

Even though there were significant pairwise differences in mean interest/enjoyment scores, there were no significant pairwise differences in mean overall response rates. As a result, we did not find evidence for H1, that a positive relationship exists between mean interest/enjoyment scores and mean overall response rate across topics.

Table 4: Pairwise comparisons of overall response rate across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	0.0867	0.0561	192	1.546	0.4120
COVID-19 – Mental Health	0.0520	0.0536	192	0.971	0.7664
COVID-19 – Physical Activity	0.1198	0.0546	192	2.194	0.1285
Diet & Nutrition – Mental Health	-0.0347	0.0551	192	-0.629	0.9225
Diet & Nutrition – Physical Activity	0.0331	0.0561	193	0.590	0.9351
Mental Health – Physical Activity	0.0678	0.0536	192	1.265	0.5863

Table 5: Pairwise comparisons of interest/enjoyment subscale scores across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	-2.070	0.203	192	-10.217	$<.0001$
COVID-19 – Mental Health	-1.373	0.194	192	-7.087	$<.0001$
COVID-19 – Physical Activity	-2.197	0.197	192	-11.136	$<.0001$
Diet & Nutrition – Mental Health	0.697	0.199	192	3.503	0.0032
Diet & Nutrition – Physical Activity	-0.127	0.203	193	-0.627	0.9234
Mental Health – Physical Activity	-0.825	0.194	192	-4.258	0.0002

To compare differences in mean overall response rate to differences in mean perceived choice subscale scores, we created a linear mixed effects model for perceived choice scores. We plot the mean perceived choice scores and 95% confidence intervals in Figure 2b.

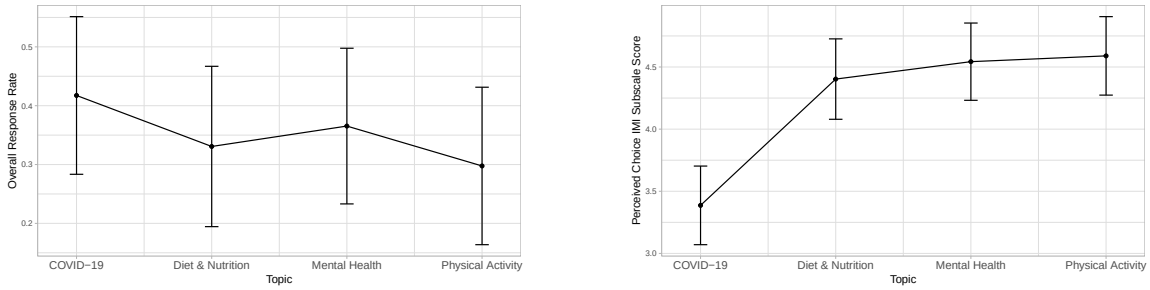
The topic with the highest mean perceived choice score was physical activity, as seen in Figure 2b. However in Figure 2a, the mean overall response rate for physical activity was the lowest among all four topics. Conversely, COVID-19 had the lowest mean perceived choice score among the topics, but had the highest mean overall response rate. These findings did not support H1, that higher average perceived choice subscale scores for a topic should correspond to higher average overall response rate for that topic compared to others.

From our post-hoc analysis, we found the difference in mean perceived choice subscale scores for pairwise comparisons COVID-19 – diet & nutrition, COVID-19 – mental health, and COVID-19 – physical activity were all significant at $p < .0001$, as evident in Table 6.

Although there were significant pairwise differences in mean perceived choice scores, there were no significant pairwise differences in mean overall response rates as seen in Table 4. Thus, we did not find support for H1's prediction of a positive relationship between mean perceived choice scores and mean overall response rate across topics.

Table 6: Pairwise comparisons of perceived choice subscale scores across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	-1.0163	0.154	193	-6.578	<.0001
COVID-19 – Mental Health	-1.1564	0.148	192	-7.828	<.0001
COVID-19 – Physical Activity	-1.2029	0.150	192	-7.995	<.0001
Diet & Nutrition – Mental Health	-0.1401	0.152	193	-0.923	0.7928
Diet & Nutrition – Physical Activity	-0.1867	0.155	193	-1.207	0.6232
Mental Health – Physical Activity	-0.0466	0.148	192	-0.316	0.9891



(a) Overall Response Rate by Topic

(b) Perceived Choice Score by Topic

Figure 2: Comparing variation in overall response rate to variation in perceived choice scores across topics

For comparing differences in mean overall response rate to differences in mean perceived competence subscale scores, we created a linear mixed effects model for perceived competence scores. We plot the mean perceived competence scores and 95% confidence intervals in Figure 3b.

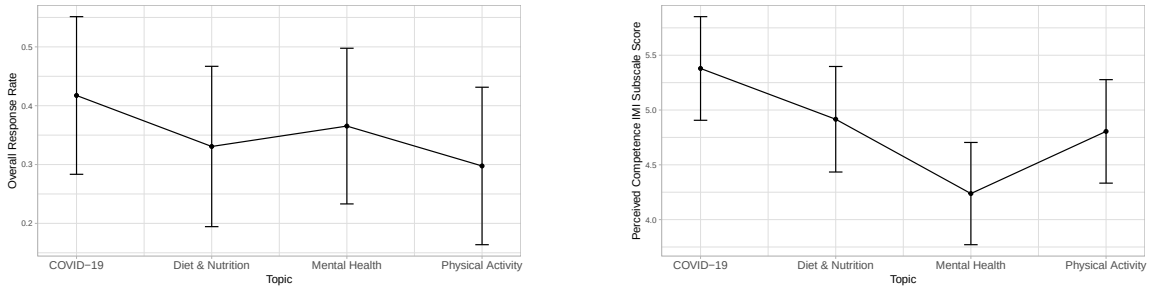
As seen in Figure 3b, mental health had the lowest mean perceived competence score. But in Figure 3a, the overall response rate for mental health was not the lowest mean overall response rate among the four topics. These findings did not support our hypothesis following from H1, that lower average perceived competence subscale scores for a topic should correspond to lower average overall response rate for that topic in comparison to others.

For our post-hoc analysis, we ran a Tukey HSD test on the perceived competence linear mixed effects model to test whether the differences between the perceived competence subscale scores were significant. As shown in 6, the difference in mean perceived competence subscale scores for the pairwise comparison of COVID-19 – mental health was significant at $p < .0001$. The pairwise difference for diet & nutrition – mental health was significant at $p < .01$, while COVID-19 – physical activity and mental health – physical activity were both significant at $p < .05$.

Despite significant pairwise differences in mean perceived competence scores, there were no significant pairwise differences in mean overall response rate. These findings did not support H1, that a positive relationship exists between mean perceived competence scores and mean overall response rate across topics.

Table 7: Pairwise comparisons of perceived competence subscale scores across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	0.463	0.205	192	2.256	0.1121
COVID-19 – Mental Health	1.142	0.196	192	5.814	<.0001
COVID-19 – Physical Activity	0.574	0.200	192	2.871	0.0234
Diet & Nutrition – Mental Health	0.678	0.202	192	3.360	0.0052
Diet & Nutrition – Physical Activity	0.111	0.206	193	0.539	0.9494
Mental Health – Physical Activity	-0.567	0.196	192	-2.891	0.0221



(a) Overall Response Rate by Topic

(b) Perceived Competence Score by Topic

Figure 3: Comparing variation in overall response rate to variation in perceived competence scores across topics

To compare differences in mean overall response rate to differences in mean value/usefulness subscale scores, we created a linear mixed effects model for value/usefulness subscale scores. Figure 4b plots the mean value/usefulness subscale score and 95% confidence interval for each topic.

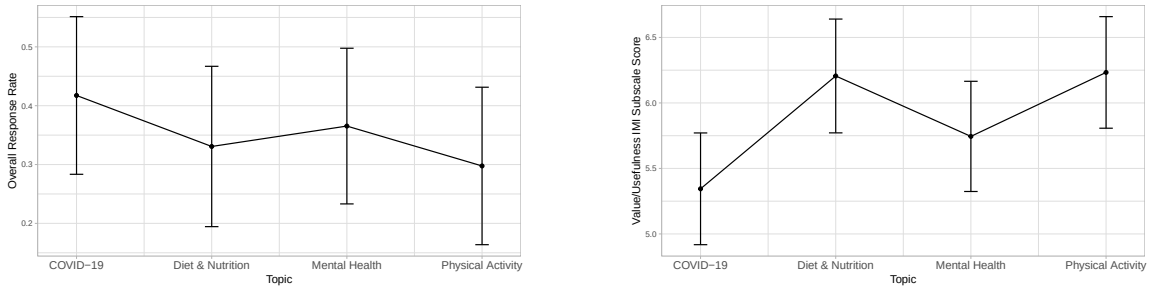
The two topics with the highest mean value/usefulness scores were diet & nutrition and physical activity, as seen in Figure 4b. In Figure 4a, the mean overall response rates for diet & nutrition and physical activity were lower than the mean overall response rate for the other topics. Conversely, COVID-19 had the lowest mean value/usefulness score among the topics, but the highest mean overall response rate. These findings did not support H1, that higher average value/usefulness subscale scores for a topic should correspond to higher average overall response rate for that topic compared to others.

Our Tukey test results in Table 6 found the differences in mean value/usefulness subscale scores for pairwise comparisons COVID-19 – diet & nutrition and COVID-19 – physical activity were significant at $p < .0001$. In addition, the pairwise difference for mental health – physical activity was significant at $p < .05$.

Because there were no significant differences in mean overall response rates, this evidence did not support H1's prediction of a positive relationship between mean value/usefulness scores and mean overall response rate across topics.

Table 8: Pairwise comparisons of value/usefulness subscale scores across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	-0.861	0.187	192	-4.614	<.0001
COVID-19 – Mental Health	-0.400	0.178	192	-2.242	0.1158
COVID-19 – Physical Activity	-0.888	0.182	192	-4.886	<.0001
Diet & Nutrition – Mental Health	0.461	0.183	192	2.514	0.0609
Diet & Nutrition – Physical Activity	-0.027	0.187	193	-0.145	0.9989
Mental Health – Physical Activity	-0.488	0.178	192	-2.737	0.0340



(a) Overall Response Rate by Topic

(b) Value/Usefulness Score by Topic

Figure 4: Comparing variation in overall response rate to variation in value/usefulness scores across topics

In our final analysis for overall response rate, we created a linear mixed effects model for the total IMI score. We plot the mean total IMI score for each topic in Figure 5a, along with the corresponding 95% confidence intervals.

The topics with the highest mean total IMI score were diet & nutrition and physical activity, as seen in Figure 5b. In Figure 5a, the mean overall response rates for diet & nutrition and physical activity were lower than the mean overall response rate for other topics. Conversely, COVID-19 had the lowest mean total IMI score, but the highest mean overall response rate among the topics. These results do not support H1, that a higher total IMI score for an intervention topic should correspond to a higher average overall response rate for that topic compared to others.

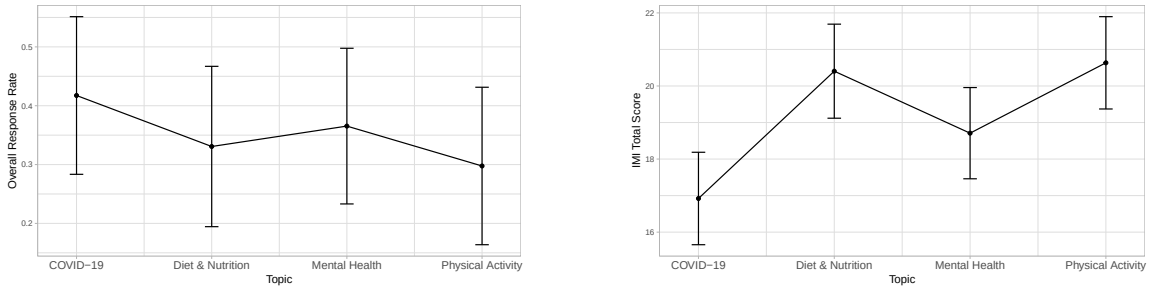
As shown by our Tukey test results in Table 6, the differences in total IMI scores for pairwise comparisons COVID-19 – diet & nutrition and COVID-19 – physical activity were significant at $p < .0001$. The pairwise differences for COVID-19 – mental health, diet & nutrition – mental health, and mental health – physical activity were significant at $p < .01$.

Because there were no significant differences in mean overall response rates, this evidence did not support H1, that a positive relationship exists between mean total IMI scores and mean overall response rate across topics.

To summarize our analyses of overall response rate, we found that differences in mean overall response rate were statistically insignificant, and did not reflect the significant pairwise differences in mean interest/enjoyment, perceived choice, perceived competence, and value/usefulness subscale scores. The differences in mean overall response rate also did not reflect the significant pairwise differences in mean total IMI scores. These results did not provide evidence for H1, that a positive relationship exists between mean intrinsic motivation measures and mean overall response rate across topics.

Table 9: Pairwise comparisons of total IMI scores across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	-3.484	0.539	192	-6.468	<.0001
COVID-19 – Mental Health	-1.788	0.515	192	-3.471	0.0035
COVID-19 – Physical Activity	-3.713	0.525	192	-7.078	<.0001
Diet & Nutrition – Mental Health	1.697	0.529	192	3.205	0.0085
Diet & Nutrition – Physical Activity	-0.229	0.539	193	-0.424	0.9743
Mental Health – Physical Activity	-1.925	0.515	192	-3.741	0.0014



(a) Overall Response Rate by Topic

(b) Total IMI Score by Topic

Figure 5: Comparing variation in overall response rate to variation in total IMI scores across topics

5.1.2 Just-in-Time Response Rate

We defined *just-in-time response rate* as the fraction of initiating messages a participant responded to within ten minutes of delivery, over a given time period. Because we defined just-in-time response as a stricter condition than response, we extended H1 to predict that a positive relationship exists between mean intrinsic motivation measures and just-in-time response rate across topics.

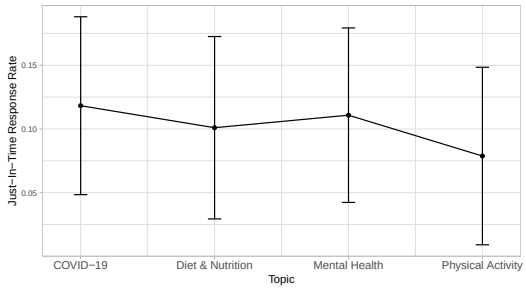
To compare differences in mean just-in-time response rates across topics to differences in mean IMI subscale scores and total IMI scores across topics, we constructed a linear mixed effects model for just-in-time response rate. We plot the mean just-in-time response rates and corresponding 95% confidence intervals in Figure 6a.

The pairwise differences in mean just-in-time response rate were small and statistically insignificant as shown by the Tukey test results in Table 10. In contrast, there were significant pairwise differences in mean interest/enjoyment scores in Table 5, perceived choice scores in Table 6, perceived competence scores in Table 7, value/usefulness scores in Table 8, and total IMI scores in Table 9. Because the differences in mean just-in-time response rate were statistically insignificant and did not reflect the significant differences in mean IMI subscale scores and total IMI scores, we did not find evidence for the hypothesis following from H1, that a positive relationship exists between mean intrinsic motivation scores and mean just-in-time response rate across topics.

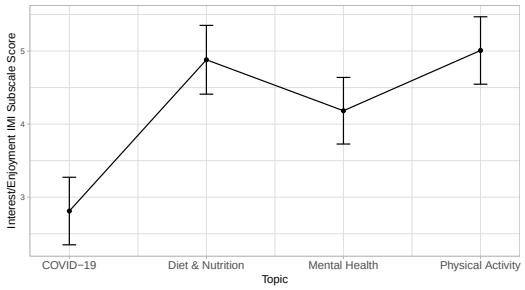
To visualize this lack of relationship, we plotted the linear mixed effects model for just-in-time response rate in Figure 6a repeated next to the plotted linear mixed effects models for interest/enjoyment subscale scores in Figure 6b, perceived choice subscale scores in Figure 7b, perceived competence subscale scores in Figure 8b, value/usefulness subscale scores in Figure 9b, and total IMI scores in Figure 10b. As shown in these figures, the mean just-in-time response rate did not differ much across topics, while the IMI subscale scores and total IMI scores vary significantly across topics.

Table 10: Pairwise comparisons of just-in-time response rate across topics

Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	0.01728	0.0359	193	0.481	0.9632
COVID-19 – Mental Health	0.00746	0.0343	192	0.217	0.9964
COVID-19 – Physical Activity	0.03951	0.0350	192	1.130	0.6715
Diet & Nutrition – Mental Health	-0.00982	0.0353	193	-0.278	0.9924
Diet & Nutrition – Physical Activity	0.02223	0.0359	193	0.618	0.9261
Mental Health – Physical Activity	0.03205	0.0343	192	0.934	0.7866

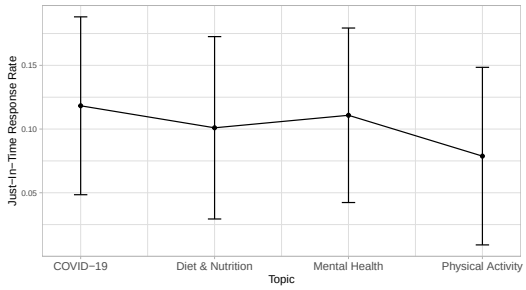


(a) Just-in-Time Response Rate by Topic

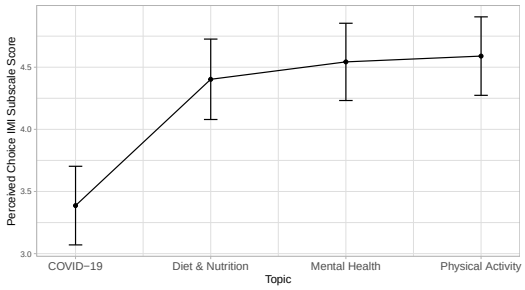


(b) Interest/Enjoyment Score by Topic

Figure 6: Comparing variation in just-in-time response rate to variation in interest/enjoyment scores across topics

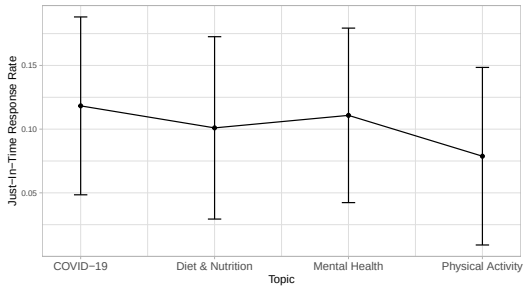


(a) Just-in-Time Response Rate by Topic

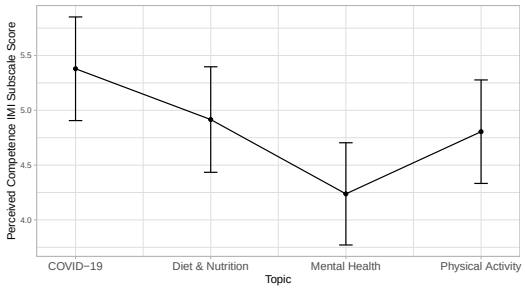


(b) Perceived Choice Score by Topic

Figure 7: Comparing variation in just-in-time response rate to variation in perceived choice scores across topics

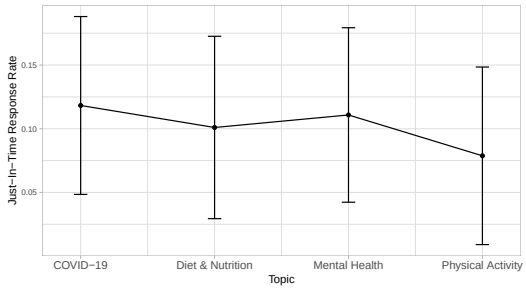


(a) Just-in-Time Response Rate by Topic

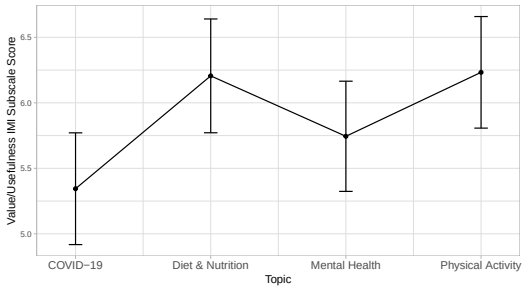


(b) Perceived Competence Score by Topic

Figure 8: Comparing variation in just-in-time response rate to variation in perceived competence scores across topics

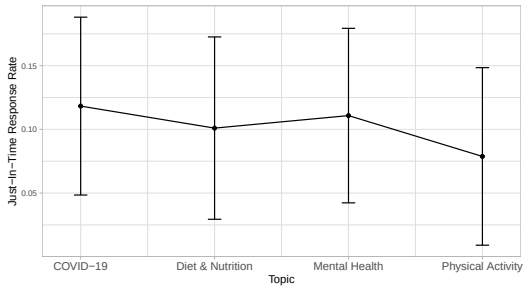


(a) Just-in-Time Response Rate by Topic

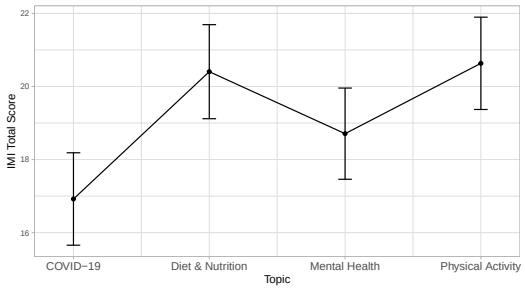


(b) Value/Usefulness Score by Topic

Figure 9: Comparing variation in just-in-time response rate to variation in value/usefulness scores across topics



(a) Just-in-Time Response Rate by Topic



(b) Total IMI Score by Topic

Figure 10: Comparing variation in just-in-time response rate to variation in total IMI scores across topics

5.1.3 Conversation Rate

We defined the receptivity metric conversation rate as the fraction of initiating messages for which the participant engaged in a conversation and completed the intervention, over a given period. Because a higher conversation rate indicates greater receptivity, we extended H1 to predict that a positive relationship exists between mean intrinsic motivation measures and conversation rate across topics.

To compare differences in mean conversation rates across topics to differences in mean IMI subscale scores across topics, we constructed a linear mixed effects model for conversation rate. We plotted the mean conversation rate and accompanying 95% confidence intervals in Figure 11a.

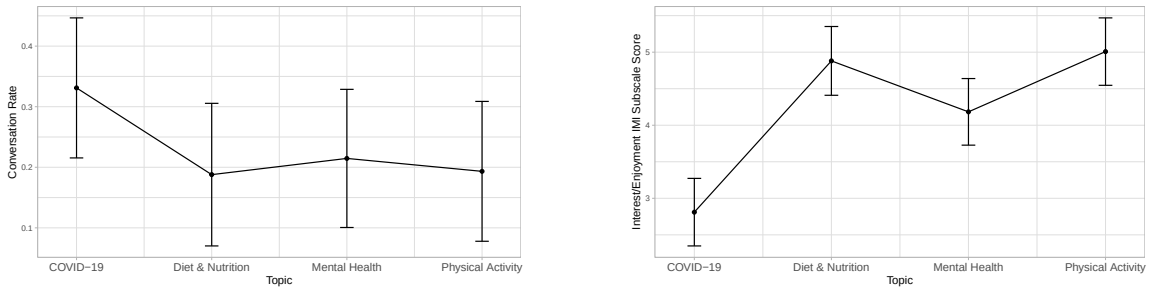
The pairwise differences in mean conversation rate were mostly small and statistically insignificant as shown by the Tukey test results in Table 11. Only pairwise differences in conversation rate for COVID-19 – diet & nutrition and COVID-19 – physical activity were significant at $p < .05$. Both estimates were positive, with the estimated mean difference in conversation rate for COVID-19 – diet & nutrition equal to 0.143 and the estimated mean difference in conversation rate for COVID-19 – physical activity equal to 0.138.

The same pairwise comparisons for COVID-19 – diet & nutrition and COVID-19 – physical activity were significant and negative for mean interest/enjoyment scores in Table 5, perceived choice scores in Table 6, value/usefulness scores in Table 8, and total IMI scores in Table 9. These results show that a statistically significant lower mean total IMI, interest/enjoyment, perceived choice, and value/usefulness score for COVID-19 compared to diet & nutrition and physical activity was associated with a statistically significant higher conversation rate for COVID-19 interventions compared to diet & nutrition and physical activity. These results failed to support the hypothesis following from H1, that a higher mean intrinsic motivation score for a topic should be reflected in a higher mean conversation rate for that topic compared to others.

To visualize these findings, we plotted the linear mixed effects model for conversation rate in Figure 11a repeated next to the plotted linear mixed effects models for interest/enjoyment scores in Figure 11b, perceived choice scores in Figure 12b, perceived competence scores in Figure 13b, value/usefulness scores in Figure 14b, and total IMI scores in Figure 15b. As seen in Figures 11b, 12b, 14b, and 15b, across all topics COVID-19 had the lowest, while diet & nutrition and physical activity had the two highest interest/enjoyment, perceived choice, value/usefulness, and total IMI scores. This illustrates the statistically significant negative estimates for pairwise comparisons of IMI scores for COVID-19 – diet & nutrition and COVID-19 – physical activity in Tables 5, 6, 8, and 9. But as seen in Figure 11b, COVID-19 had the highest mean conversation rate, while diet & nutrition and physical activity had the lowest mean conversation rates among all four topics. This figure visualizes the statistically significant positive estimates for pairwise comparisons of conversation rate for COVID-19 – diet & nutrition and COVID-19 – physical activity in Table 11. These results presented the opposite of the positive relationship predicted between IMI scores and conversation rate.

Table 11: Pairwise comparisons of conversation rate across topics

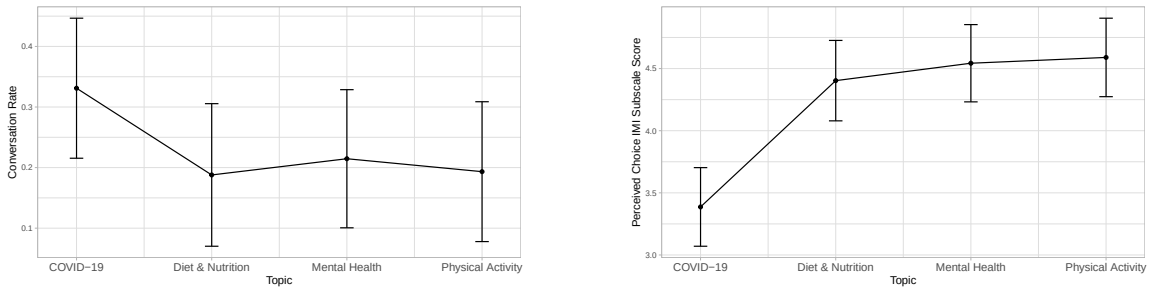
Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	0.14318	0.0501	192	2.856	0.0244
COVID-19 – Mental Health	0.11642	0.0479	192	2.429	0.0750
COVID-19 – Physical Activity	0.13774	0.0488	192	2.821	0.0269
Diet & Nutrition – Mental Health	-0.02676	0.0493	192	-0.543	0.9483
Diet & Nutrition – Physical Activity	-0.00544	0.0502	193	-0.108	0.9995
Mental Health – Physical Activity	0.02133	0.0479	192	0.445	0.9705



(a) Conversation Rate by Topic

(b) Interest/Enjoyment Score by Topic

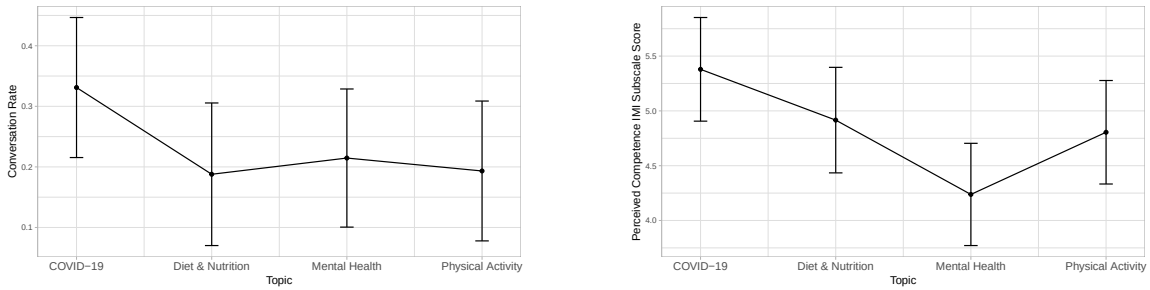
Figure 11: Comparing variation in conversation rate to variation in interest/enjoyment scores across topics



(a) Conversation Rate by Topic

(b) Perceived Choice Score by Topic

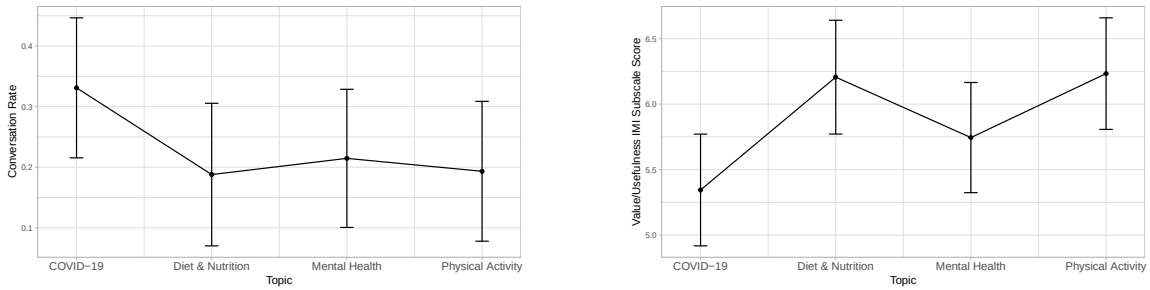
Figure 12: Comparing variation in conversation rate to variation in perceived choice scores across topics



(a) Conversation Rate by Topic

(b) Perceived Competence Score by Topic

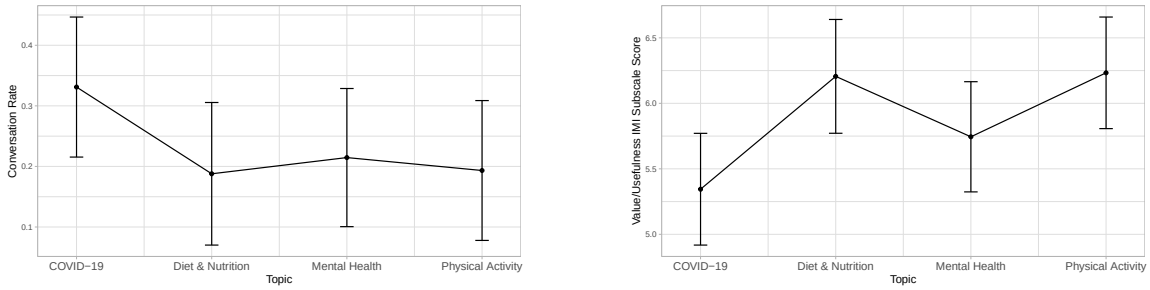
Figure 13: Comparing variation in conversation rate to variation in perceived competence scores across topics



(a) Conversation Rate by Topic

(b) Value/Usefulness Score by Topic

Figure 14: Comparing variation in conversation rate to variation in value/usefulness scores across topics



(a) Conversation Rate by Topic

(b) Total IMI Score by Topic

Figure 15: Comparing variation in conversation rate to variation in total IMI scores across topics

5.1.4 Average Response Delay

We defined *average response delay* as the mean response delay over a given time period. We interpreted lower average response delay as indicating greater receptivity to an intervention. Thus H2 predicts that a higher mean intrinsic motivation score for a topic should correspond to a lower mean average response delay compared to other topics.

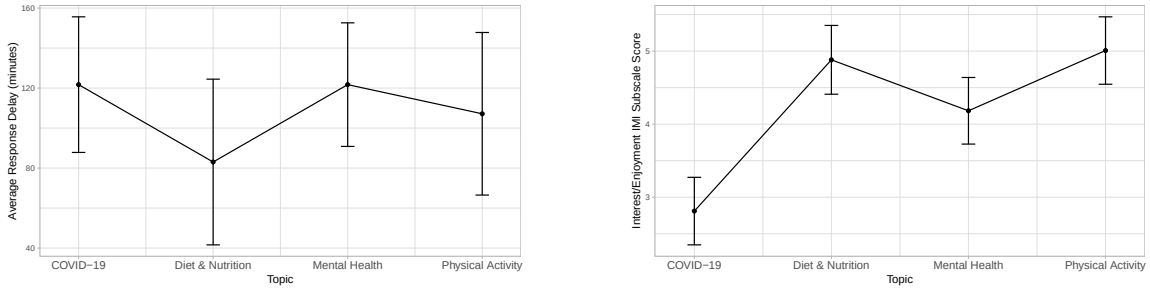
To compare differences in mean average response delay across topics to differences in mean IMI subscale scores across topics, we constructed a linear mixed effects model for average response delay. We plot the mean average response delay and corresponding 95% confidence intervals in Figure 16a.

The pairwise differences in mean average response delay were small and statistically insignificant as shown by the Tukey test results in Table 12. In contrast, there were significant pairwise differences in mean interest/enjoyment scores in Table 5, perceived choice scores in Table 6, perceived competence scores in Table 7, value/usefulness scores in Table 8, and total IMI scores in Table 9. These results failed to support H2, which argues that significant differences in mean intrinsic motivation scores across topics should be reflected as differences in mean average response delay across topics.

We then plotted the linear mixed effects model for average response delay in Figure 16a repeated next to the plotted linear mixed effects models for interest/enjoyment scores in Figure 16b, perceived choice in Figure 17b, perceived competence scores in Figure 18b, value/usefulness in Figure 19b, and total IMI scores in Figure 20b. For the mean total IMI scores and mean subscale scores for interest/enjoyment, perceived choice, value/usefulness, COVID-19 was the lowest among all four topics. As seen in Figure 16, there was a negative trend between mean interest/enjoyment scores and mean average response delay by topic. There was also a negative trend between mean perceived value scores and mean average response delay as seen in Figure 19, and a negative trend between mean total IMI scores and mean average response delay by topic as seen in Figure 20. Although the pairwise differences in mean average response delay were insignificant, with more data these negative trends might become significant and support H2's prediction that a higher mean intrinsic motivation score for a topic should be associated with lower mean average response delay compared to other topics.

Table 12: Pairwise comparisons of average response delay across topics

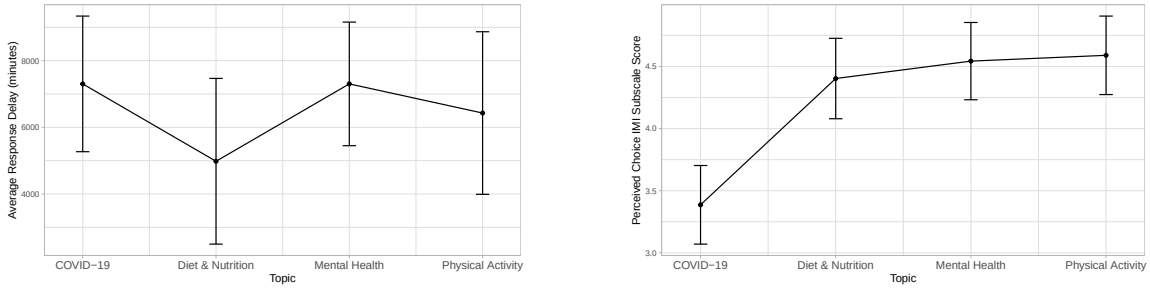
Pairwise Comparisons	Estimate	Std. Error	df	t-ratio	p-value
COVID-19 – Diet & Nutrition	2.32e+03	1627	131	1.427	0.4850
COVID-19 – Mental Health	-5.99e-02	1383	125	0.000	1.0000
COVID-19 – Physical Activity	8.74e+02	1600	126	0.547	0.9473
Diet & Nutrition – Mental Health	-2.32e+03	1564	127	-1.484	0.4499
Diet & Nutrition – Physical Activity	-1.45e+03	1756	126	-0.824	0.8430
Mental Health – Physical Activity	8.74e+02	1543	126	0.567	0.9418



(a) Average Response Delay by Topic (minutes)

(b) Interest/Enjoyment Score by Topic

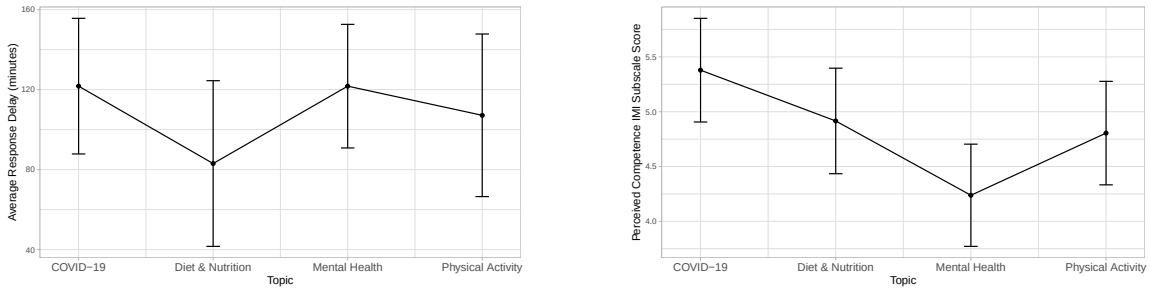
Figure 16: Comparing variation in average response delay to variation in interest/enjoyment scores across topics



(a) Average Response Delay by Topic (minutes)

(b) Perceived Choice Score by Topic

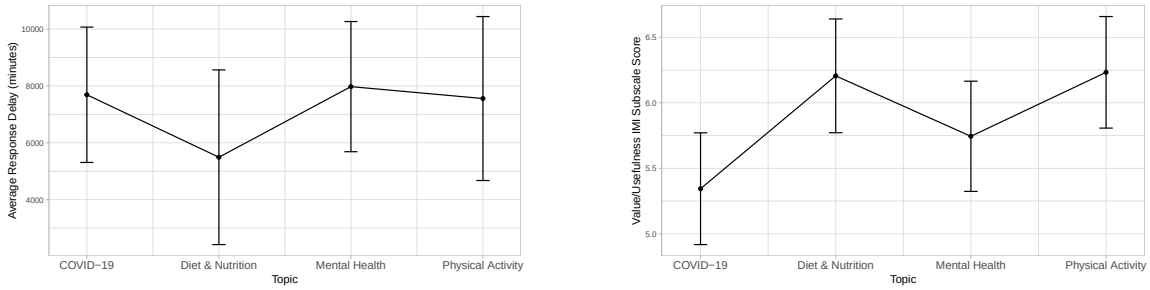
Figure 17: Comparing variation in average response delay to variation in perceived choice scores across topics



(a) Average Response Delay by Topic (minutes)

(b) Perceived Competence Score by Topic

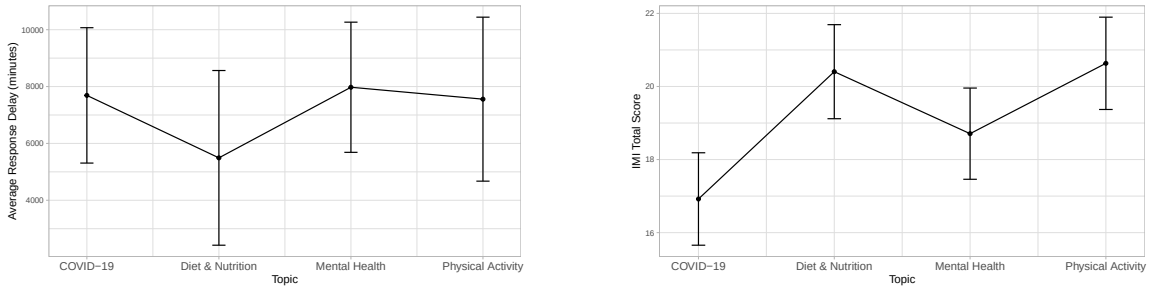
Figure 18: Comparing variation in average response delay to variation in perceived competence scores across topics



(a) Average Response Delay by Topic (minutes)

(b) Perceived Value Score by Topic

Figure 19: Comparing variation in average response delay to variation in value/usefulness scores across topics



(a) Average Response Delay by Topic (minutes)

(b) Total IMI Score by Topic

Figure 20: Comparing variation in average response delay to variation in total IMI scores across topics

5.2 H3 and H4 – Exploring Whether a Relationship Exists Between IMI Subscale Scores and Receptivity In-the-Moment Within a Topic

In this section, we evaluate whether there was a relationship between IMI subscale scores and metrics for receptivity in-the-moment, which include response, just-in-time response, conversation engagement, and response delay. For the binary variables response, just-in-time response, and conversation engagement, we used generalized linear mixed effects models. For the continuous variable response delay, we used linear mixed effects models. We set the fixed effects as IMI subscale scores for interest/enjoyment, perceived choice, perceived competence, and value/usefulness. There were 20 groups, the number of participants who completed the study.

5.2.1 Response

We defined response as a binary variable for whether a participant responded to an initiating message during the interval in which it was delivered.

For mental health initiating messages, we found a one-point increase in the perceived choice subscale score was associated with a statistically significant 11.4% increase in the log likelihood of response, with $\chi^2(1) = 12.400, p < .001$. The perceived choice subscale is theorized to positively predict self-report and behavioral measures of intrinsic motivation. Thus, this result supported H3's prediction that the higher a participant's intrinsic motivation for a topic, the higher the likelihood that the participant responds to messages for that topic.

Also for mental health interventions, we found a one-point increase in the value/usefulness subscale score was associated with a statistically-significant increase in the log likelihood of response by 6.83%, with $\chi^2(1) = 5.886, p < .05$. The value/usefulness subscale is theorized to indicate internalization, as people internalize and self-regulate activities they view as valuable and useful for themselves [23]. So the positive relationship found between value/usefulness subscale scores and the log-likelihood of response perhaps indicated that participants with high value/usefulness scores have internalized the behavior of responding to initiating messages about mental health. This result also corroborated Mehrotra's findings that people are more likely to accept disruptive phone notifications with content they view as important, urgent, or useful [15].

Regarding initiating messages for COVID-19 interventions, we found a statistically-significant negative relationship between the interest/enjoyment IMI subscale score and the log likelihood of response. A one-point increase in the interest/enjoyment IMI subscale score was associated with a decrease in the log likelihood of response by 10.5%, with $\chi^2(1) = 6.336, p < .05$. Since the interest/enjoyment subscale is theorized to be a self-report of intrinsic motivation, this result counters H3's prediction that the higher a participant's intrinsic motivation score for a topic, the higher the likelihood that the participant responds to messages for that topic.

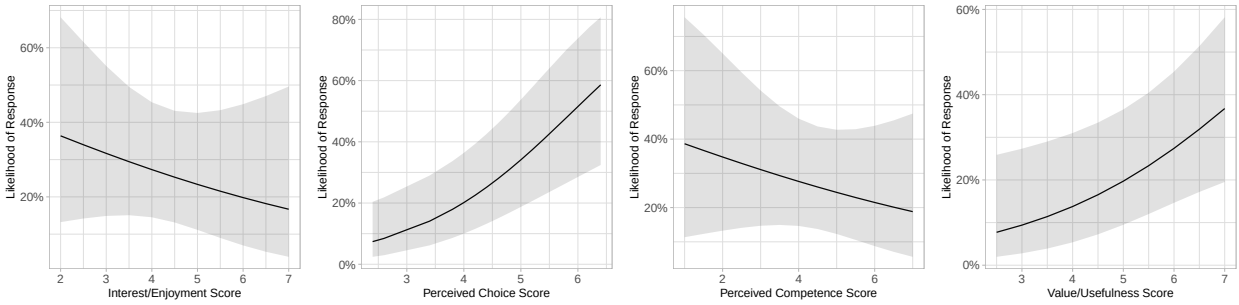
We then visualized the relationship between the four IMI subscale scores and the likelihood of response to interventions about mental health in Figure 21, COVID-19 in Figure 22, physical activity in Figure 23, and diet & nutrition in Figure 24. The x-axis specified the IMI subscale and the range of subscale scores observed, while the y-axis displayed the likelihood of response as a percentage. In each figure, the plotted line depicts the mean and the shaded region represents the 95% confidence interval. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the likelihood of response. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the likelihood of response.

Of the four IMI subscales, only the value/usefulness subscale had a positive relationship with the likelihood of response for all four intervention topics, as evident in Figures 21d, 22d, 23d, and 24d. While this positive relationship was significant only for mental health, with more data the general trend might become

significant and support H3, that a higher value/usefulness score for a topic should be associated with a higher likelihood of response to interventions for that topic.

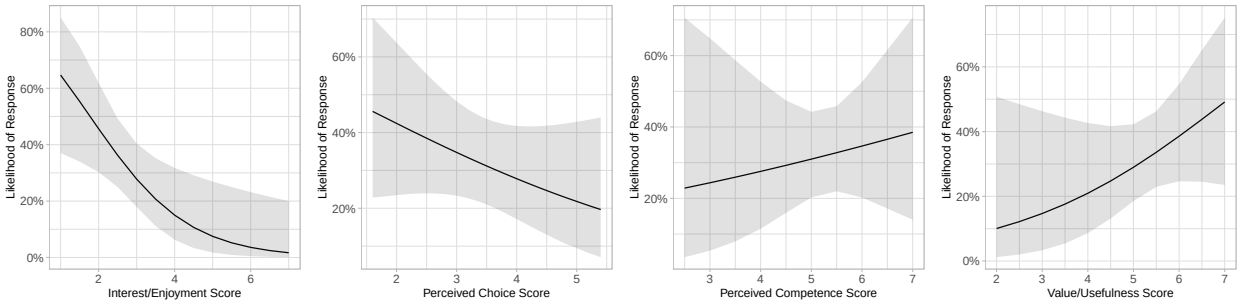
We also observed a negative relationship between the interest/enjoyment subscale and the likelihood of response for mental health, COVID-19, and diet & nutrition (see Figures 21a, 22a, and 24a). This suggests that for these three topics, an increase in interest/enjoyment subscale scores was associated with a decrease in the likelihood of response. This negative relationship was only statistically significant for COVID-19.

For more details on the effects of all four IMI subscales on response to the four intervention topics, please view Appendix Tables 17, 18, 19, and 20.



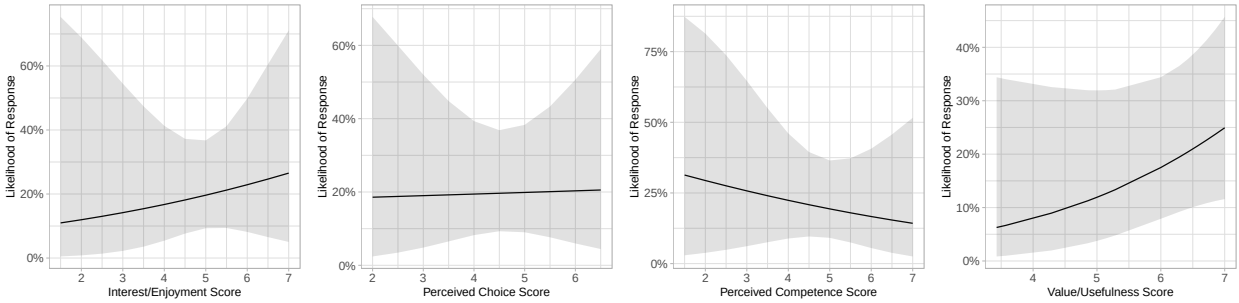
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 21: Effect of IMI subscale scores on likelihood of response to mental health interventions



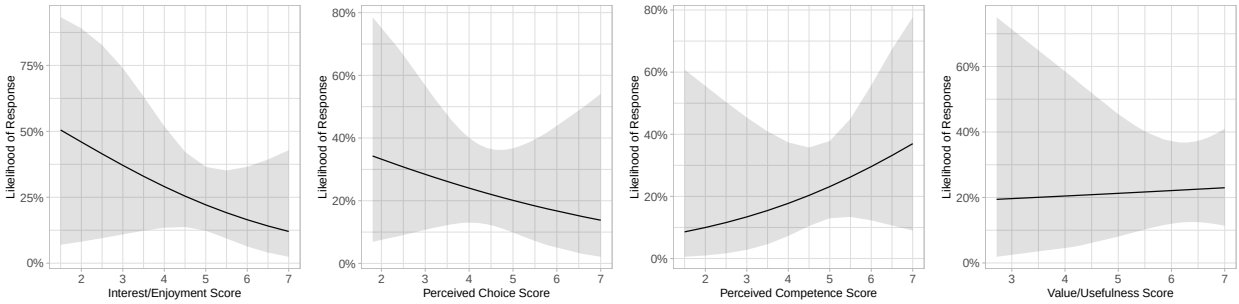
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 22: Effect of IMI subscale scores on likelihood of response to COVID-19 interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 23: Effect of IMI subscale scores on likelihood of response to physical activity interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 24: Effect of IMI subscale scores on likelihood of response to diet & nutrition interventions

5.2.2 Just-in-Time Response

We recorded an instance of just-in-time response if a participant responded to an initiating message within ten minutes of when it was delivered. Because we defined just-in-time response as a stricter condition than response, we extended H3 to predict that a higher intrinsic motivation score for a topic should be associated with a higher likelihood of the participant having just-in-time responses to interventions for that topic.

In our analysis, we were unable to find any significant relationships between IMI subscale scores and just-in-time response. See Appendix Tables 17, 18, 19, and 20 for more details on the effects of all four IMI subscales on just-in-time response to the four intervention topics.

We visualized the relationships between each IMI subscale score and the likelihood for just-in-time response to interventions about mental health in Appendix Figure 43, COVID-19 in Appendix Figure 44, physical activity in Appendix Figure 45, and diet & nutrition in Appendix Figure 46. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the likelihood of just-in-time response. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the likelihood of just-in-time response.

We found a statistically insignificant positive slope between value/usefulness subscale scores and the likelihood of just-in-time response to interventions about mental health, COVID-19, and physical activity, as evident in Appendix Figures 43d, 44d, and 45d. With more data, these positive trends may become significant and support the hypothesis following from H3, that a higher value/usefulness score for a topic should be associated with a higher likelihood of the participant having just-in-time responses to interventions for that topic.

For all four intervention topics, there was a statistically insignificant negative slope for the relationship between interest/enjoyment subscale scores and the likelihood of just-in-time response, as seen in Appendix Figures 43a, 44a, 45a, 46a.

5.2.3 Conversation Engagement

We defined conversation engagement as true if a participant completed the intervention in the time interval (morning, afternoon, evening) in which it was delivered. Because a higher conversation rate indicates greater receptivity, we extended H3 to predict that a higher intrinsic motivation score for a topic should be associated with a higher likelihood of conversation engagement for interventions about that topic.

Our analysis yielded no significant relationships between IMI subscale scores and conversation engagement. See Appendix Tables 17, 18, 19, and 20 for more details on the effects of all four IMI subscales on conversation engagement for the four intervention topics.

We plotted the relationships between each IMI subscale score and the conversation engagement with interventions about mental health in Appendix Figure 47, COVID-19 in Appendix Figure 48, physical activity in Appendix Figure 49, and diet & nutrition in Appendix Figure 50. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the likelihood of conversation engagement. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the likelihood of conversation engagement.

We found a statistically insignificant positive slope for the relationship between perceived competence subscale scores and likelihood of conversation engagement for all four intervention topics, as shown in Appendix Figures 47c, 48c, 49c, and 50c. With more data, these positive trends may become significant and support the hypothesis following from H3, that having higher perceived competence for a topic increases the likelihood of a participant engaging with and completing interventions for that topic.

Similarly, we found a statistically insignificant positive slope for the relationship between value/usefulness subscale scores and the likelihood of conversation engagement with interventions about mental health, COVID-19, and physical activity, as evident in Appendix Figures 47d, 48d, and 49d. With more data,

these positive trends may become significant and support the hypothesis following from H3, that a higher value/usefulness score for a topic should be associated with a higher likelihood of the participant engaging with and completing interventions for that topic.

For all four topics, there was a statistically insignificant negative slope between interest/enjoyment subscale scores and the likelihood of conversation engagement, as seen in Appendix Figures 47a, 48a, 49a, and 50a.

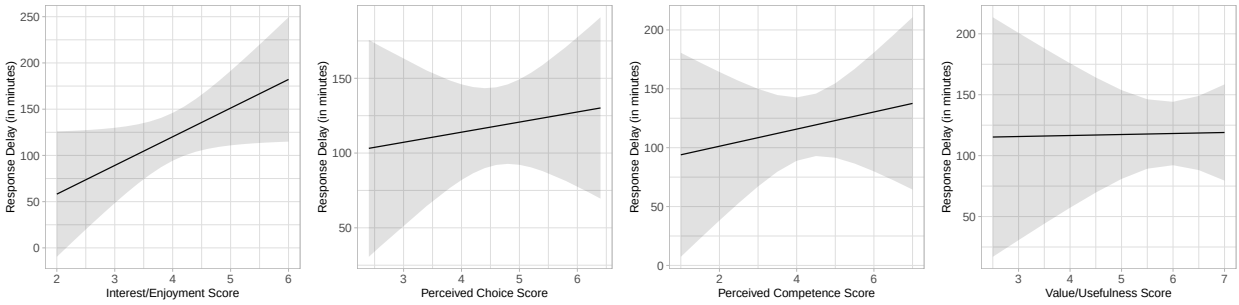
5.2.4 Response Delay

We measured response delay as the number of minutes between when a participant responded to an initiating message and when the initiating message was delivered. Any unanswered initiating messages were dropped from the data set. We interpreted lower response delay as indicating greater receptivity to an intervention.

We found that a one-point increase in the interest/enjoyment IMI subscale score was associated with an increase in the response delay to mental health interventions by 31.01 minutes, with $\chi^2(1) = 3.843, p < .05$. This result counters H4, that the higher a participant's intrinsic motivation for a topic, the lower the response delay for interventions about that topic. We were unable to find any other significant relationships between IMI subscale scores and response delay. For more details on the effects of all four IMI subscales on response delay for the four intervention topics, see Appendix Tables 17, 18, 19, and 20.

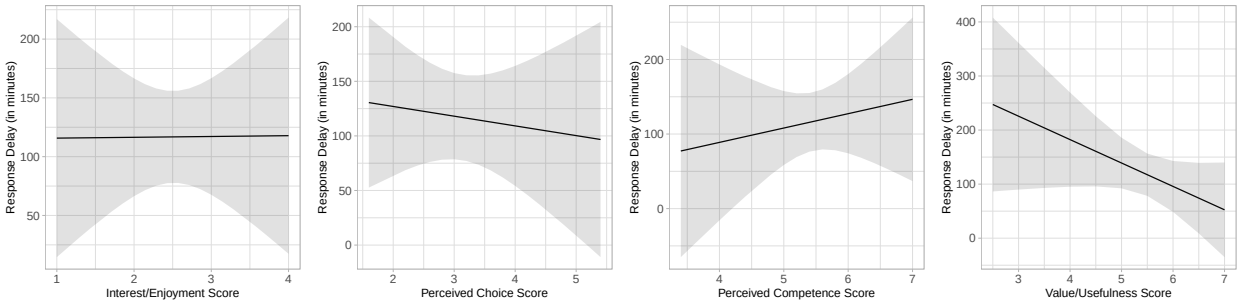
We visualized the relationships between each IMI subscale score and response delay for interventions about mental health in Figure 25, COVID-19 in Figure 26, physical activity in Figure 27, and diet & nutrition in Figure 28. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the response delay in minutes. A negative slope implies that an increase in the IMI subscale was associated with a decrease in the response delay in minutes.

For COVID-19, physical activity, and diet & nutrition, there was a statistically insignificant negative slope for the relationship between value/usefulness subscale scores and likelihood of conversation engagement, as seen in Figures 26d, 27d, and 28d. With more data, these negative trends may become significant and support H4, that is, the higher a participant's intrinsic motivation for a topic, the lower the response delay for interventions about that topic.



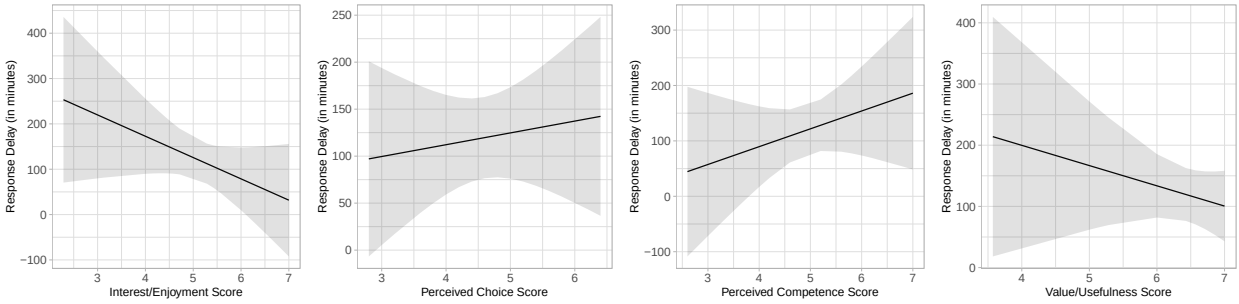
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 25: Effect of IMI subscale scores on response delay for mental health interventions



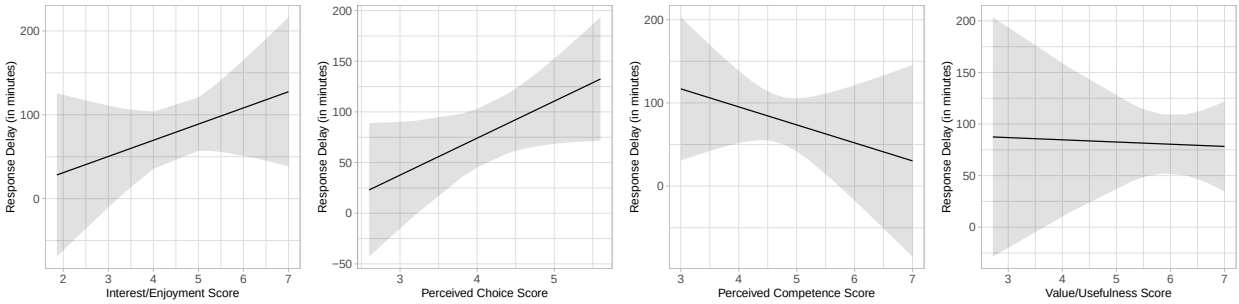
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 26: Effect of IMI subscale scores on response delay for COVID-19 interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 27: Effect of IMI subscale scores on response delay for physical activity interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 28: Effect of IMI subscale scores on response delay for diet & nutrition interventions

5.3 Exploring Whether a Relationship Exists Between Total IMI Scores and Receptivity In-the-Moment Within a Topic

In this section, we evaluate whether there was a relationship between total IMI scores and metrics for receptivity in-the-moment, which include response, just-in-time response, conversation engagement, and response delay. Total IMI scores were calculated by adding together the four IMI subscale scores.

For the binary variables response, just-in-time response, and conversation engagement, we used generalized linear mixed effects models. For the continuous variable response delay, we used linear mixed effects models. In both kinds of mixed effects models, we set the fixed effect as the total IMI score.

5.3.1 Response

We were unable to find a significant relationship between total IMI score and response for any of the four intervention topics.

In Appendix Figure 51, we plotted the relationships between total IMI score and likelihood of response for each topic. A positive slope implies that an increase in the total IMI score was associated with an increase in the likelihood of response. A negative slope implies that an increase in the total IMI score was associated with a decrease in the likelihood of response.

There was a statistically insignificant positive slope for mental health, COVID-19, and physical activity, as evident in Appendix Figures 51a, 51b, and 51c. With more data, these positive trends may become significant and support H3, that a higher total IMI score for a topic should be associated with an increases in the likelihood of response to interventions for that topic.

5.3.2 Just-in-Time Response

We did not find a significant relationship between total IMI score and just-in-time response for any of the four intervention topics.

In Appendix Figure 52, we visualized the relationships between total IMI score and likelihood of just-in-time response for each topic. A positive slope implies that an increase in the total IMI score was associated with an increase in the likelihood of just-in-time response. A negative slope implies that an increase in the total IMI score was associated with a decrease in the likelihood of just-in-time response.

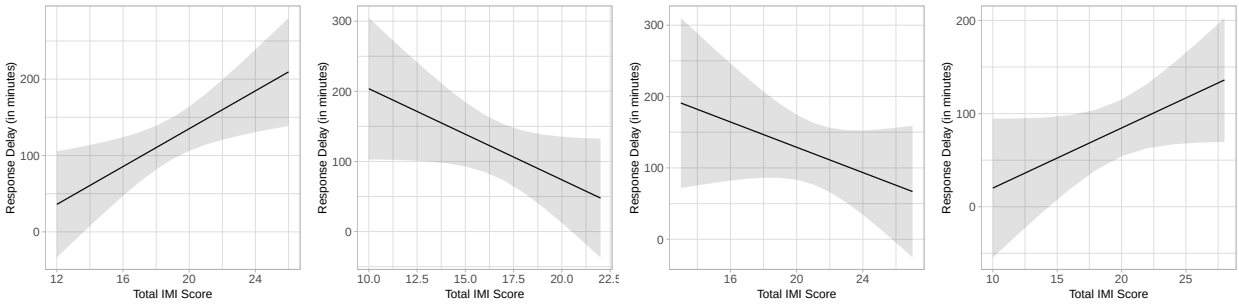
For COVID-19 and physical activity, there was a statistically insignificant positive slope, as shown in Appendix Figures 52b and 52c. With more data, these positive trends may become significant and support the hypothesis following from H3, that a higher total IMI score for a topic should be associated with an increase in the likelihood of the participant responding just-in-time to interventions for that topic.

5.3.3 Conversation Engagement

There was no significant relationship between total IMI score and conversation engagement for any of the four intervention topics.

In Appendix Figure 53, we plotted the relationships between total IMI score and likelihood of conversation engagement for each topic. A positive slope implies that an increase in the total IMI score was associated with an increase in the likelihood of conversation engagement. A negative slope implies that an increase in the total IMI score was associated with a decrease in the likelihood of conversation engagement.

There was a statistically insignificant positive slope for the mental health and COVID-19 graphs, as seen in Appendix Figures 53a and 53b. With more data, these positive trends may become significant and support the hypothesis following from H3, that higher intrinsic motivation for a topic increases the likelihood of conversation engagement for interventions about that topic.



(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 29: Effect of total IMI scores on response delay for intervention topics

5.3.4 Response Delay

We found a significant positive relationship between total IMI scores and response delay. A one-point increase in the total IMI score was associated with an increase in the response delay by 12.39 minutes for mental health interventions, $\chi^2(1) = 7.009, p < .05$. This counters H4, that higher intrinsic motivation for a topic decreases the response delay for that topic.

In Figure 29, we visualize the relationships between total IMI score and response delay for each topic. A positive slope implies that an increase in the the total IMI score was associated with an increase in the response delay. A negative slope implies that an increase in the total IMI score was associated with a decrease in the response delay.

There was a statistically insignificant negative slope for COVID-19 and physical activity, as evident in Figure 29b and Figure 29c. With more data, these negative trends may become significant and support H4, that higher intrinsic motivation for a topic decreases the response delay for that topic.

5.4 Exploring Whether a Relationship Exists Between IMI Subscale Scores and Receptivity Over a Given Time Period Within a Topic

In this section, we evaluate whether there was a relationship between IMI subscale scores and metrics for receptivity over a given time period, which include overall response rate, just-in-time response rate, conversation rate, and average response delay. Because these were all defined as continuous variables, we used generalized linear mixed effects models. We set the fixed effects as IMI subscale scores for interest/enjoyment, perceived choice, perceived competence, and value/usefulness. There were 20 groups, the number of participants who completed the study.

5.4.1 Overall Response Rate

We defined overall response rate as the fraction of initiating messages that a participant responded to over a time period.

For mental health initiating messages, we found that a one-point increase in the perceived choice subscale score was associated with an increase in the overall response rate by 11.03%, with $\chi^2(1) = 4.311, p < .05$. Since the perceived choice subscale is theorized to positively predict self-report measures of intrinsic motivation, this statistically-significant positive relationship supported H3, that is, the higher a participant's intrinsic motivation for a topic, the higher the likelihood the participant will respond to initiating messages for that topic. This could also be explained in terms of Self-Determination Theory, which argues that greater perceived autonomy enhances intrinsic motivation and self-regulation of behavior. Higher perceived choice

subscale scores perhaps indicated certain participants had begun self regulating their behavior of responding to initiating messages about mental health.

We also found for mental health interventions that a one-point increase in the value/usefulness subscale score was associated with an increase in the overall response rate by 8.02%, with $\chi^2(1) = 4.114, p < .05$. Similarly, for physical activity a one-point increase in the value/usefulness subscale score was associated with an increase in the overall response rate by 13.47%, with $\chi^2(1) = 8.548, p < .01$. Because the value/usefulness subscale is theorized to indicate internalization, the positive relationship found between value/usefulness scores and overall response rate for mental health and physical activity perhaps indicated participants had internalized the value of responding to mental health and physical activity interventions.

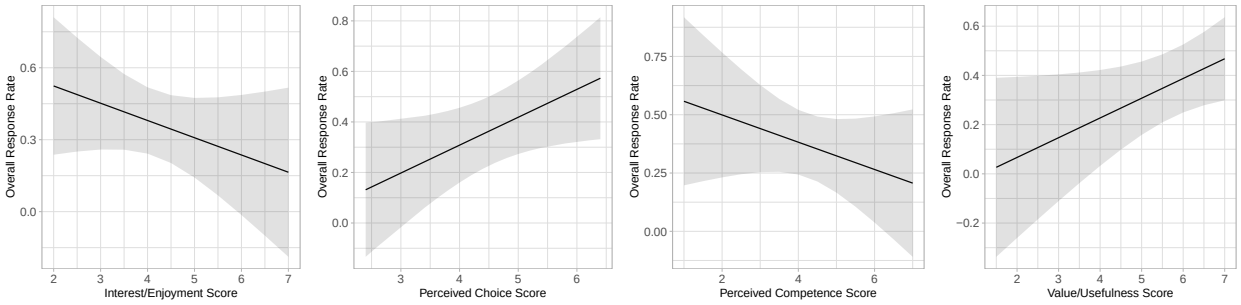
For initiating messages about COVID-19, we found a statistically significant negative relationship between the interest/enjoyment subscale score and the overall response rate. A one-point increase in the interest/enjoyment subscale score was associated with a decrease in the overall response rate by 12.69%, with $\chi^2(1) = 4.680, p < .05$.

We then visualized the relationship between the four IMI subscale scores and the overall response rate to interventions about mental health in Figure 30, COVID-19 in Figure 31, physical activity in Figure 32, and diet & nutrition in Figure 33. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the overall response rate. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the overall response rate.

Of the four IMI subscales, only the value/usefulness subscale had a positive relationship with the likelihood of response for all four intervention topics, as evident in Figures 30d, 31d, 32d, and 33d. While we found this relationship to be significant for only mental health and physical activity, the general trend across all topics aligns with H3, that a higher value/usefulness score for a topic should be associated with an increase in the overall response rate to interventions for that topic.

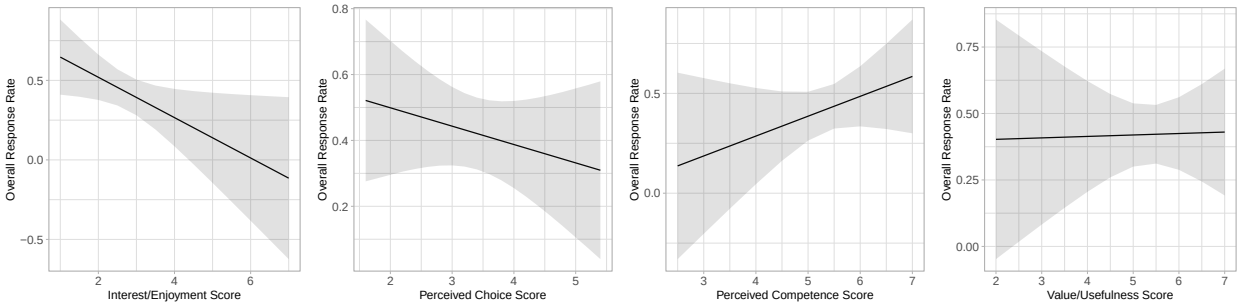
We also observed a negative relationship between the interest/enjoyment subscale and the overall response rate for all four topics (see Figures 30a, 31a, 32a, and 33a). This negative relationship was only significant for COVID-19.

For more details on the effects of all four IMI subscales on response to the four intervention topics, please view Appendix Tables 25, 26, 27, and 28.



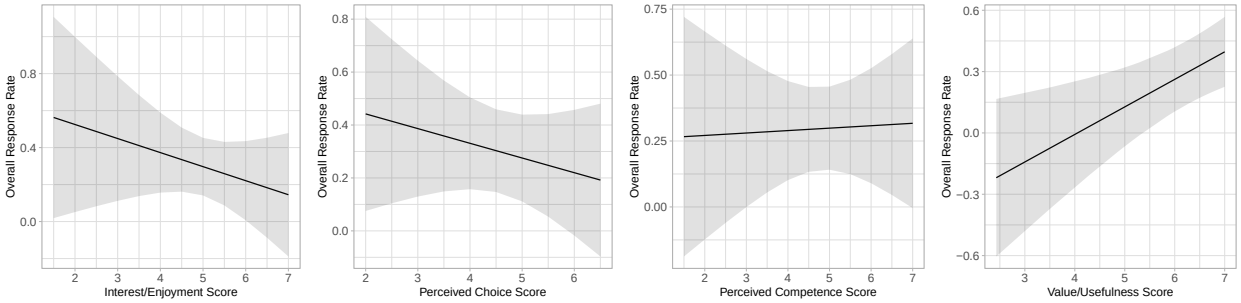
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 30: Effect of IMI subscale scores on overall response rate for mental health interventions



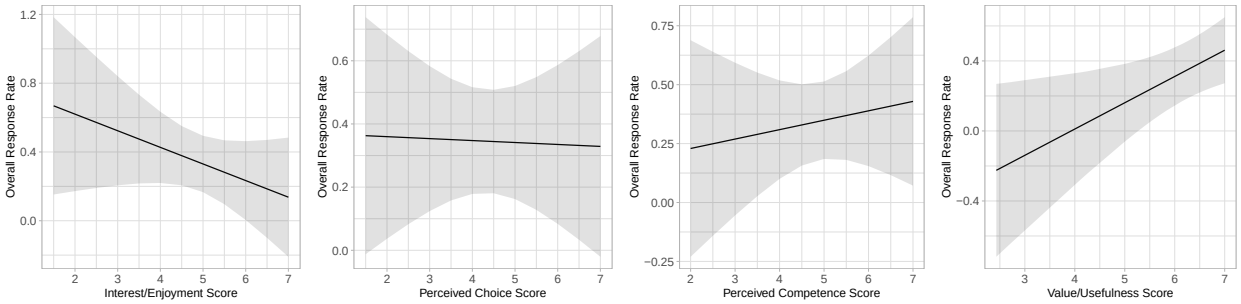
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 31: Effect of IMI subscale scores on overall response rate for COVID-19 interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 32: Effect of IMI subscale scores on overall response rate for physical activity interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 33: Effect of IMI subscale scores on overall response rate for diet & nutrition interventions

5.4.2 Just-in-Time Response Rate

We defined just-in-time response rate as the fraction of initiating messages that a participant responded to within ten minutes of delivery, over a given time period. We did not find any significant relationships between IMI subscale scores and just-in-time response rate for any of the four intervention topics. See Appendix Tables 25, 26, 27, and 28 for more details on the effects of all four IMI subscales on just-in-time response rate to the four intervention topics.

We visualized the relationships between each IMI subscale score and the just-in-time response rate to interventions about mental health in Appendix Figure 54, COVID-19 in Appendix Figure 55, physical activity in Appendix Figure 56, and diet & nutrition in Appendix Figure 57. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the just-in-time response rate. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the just-in-time response rate.

We found a statistically insignificant positive relationship between value/usefulness subscale scores and the likelihood of just-in-time response to interventions about mental health, COVID-19, and physical activity, as evident in Appendix Figures 54d, 55d, and 56d. With more data, these positive trends may become significant and support the hypothesis following from H3, that a value/usefulness score for a topic should be associated with a higher just-in-time response rate to interventions for that topic.

For all four intervention topics, there was a statistically insignificant negative slope for the relationship between interest/enjoyment subscale scores and the just-in-time response rate, as seen in Appendix Figures 54a, 55a, 56a, 57a.

5.4.3 Conversation Rate

We defined conversation rate as the fraction of initiating messages for which the participant completed the intervention, over a given time period. We were unable to find any significant relationships between IMI subscale scores and conversation rate for any of the four intervention topics. For more details on the effects of all four IMI subscales on conversation rate for the four intervention topics, see Appendix Tables 25, 26, 27, and 28.

We visualized the relationships between each IMI subscale score and the conversation rate to interventions about mental health in Appendix Figure 58, COVID-19 in Appendix Figure 59, physical activity in Appendix Figure 60, and diet & nutrition in Appendix Figure 61. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the conversation rate. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the conversation rate.

We found a statistically insignificant positive slope between value/usefulness subscale scores and the conversation rate for interventions about mental health, physical activity, and diet & nutrition, as evident in Appendix Figures 58d, 60d, and 61d. With more data, these positive trends may become significant and support the hypothesis following from H3, that a higher value/usefulness score for a topic should be associated with an increase in the participant's conversation rate for interventions about that topic.

Similarly, we also found a statistically insignificant positive slope between perceived competence subscale scores and the conversation rate for interventions about COVID-19, physical activity, and diet & nutrition, as evident in Appendix Figures 59d, 60d, and 61d. This positive trend aligns with the hypothesis following from H3, that a higher perceived/competence score for a topic should be associated with an increase in the participant's conversation rate for interventions about that topic.

For all four intervention topics, there was a statistically insignificant negative slope for the relationship between interest/enjoyment subscale scores and the conversation rate, as seen in Appendix Figures 58a, 59a, 60a, 61a.

5.4.4 Average Response Delay

We defined average response delay as the mean response delay over a given time period. We interpreted lower average response delay as indicating greater receptivity to an intervention. Thus H4 predicts that a higher intrinsic motivation score for a topic should be associated with a lower average response delay for interventions about that topic.

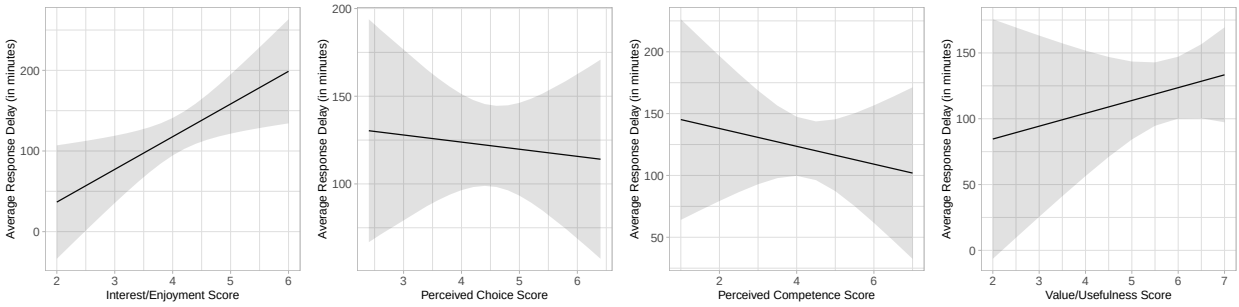
For physical activity initiating messages, we found a one-point increase in the perceived competence subscale score was associated with a decrease in the average response delay by 54.04 minutes, with $\chi^2(1) = 4.075, p < .05$. This result supported H4, that a higher perceived competence score for a topic should be associated with a lower average response delay for interventions about that topic.

We also found evidence of a statistically significant positive relationship between interest/enjoyment subscale scores and average response delay. For physical activity interventions, we found that a one-point increase in the interest/enjoyment subscale score was associated with an increase in the average response delay by 36.35 minutes, with $\chi^2(1) = 4.034, p < .05$. With regards to mental health interventions, we found that a one-point increase in the interest/enjoyment subscale score was associated with an increase in the average response delay by 40.54 minutes, with $\chi^2(1) = 6.660, p < .01$.

We visualized the relationships between each IMI subscale score and the average response delay to interventions about mental health, COVID-19, and physical activity in Figures 34, 36, and 37. A positive slope implies that an increase in the IMI subscale score was associated with an increase in the average response delay. A negative slope implies that an increase in the IMI subscale score was associated with a decrease in the average response delay.

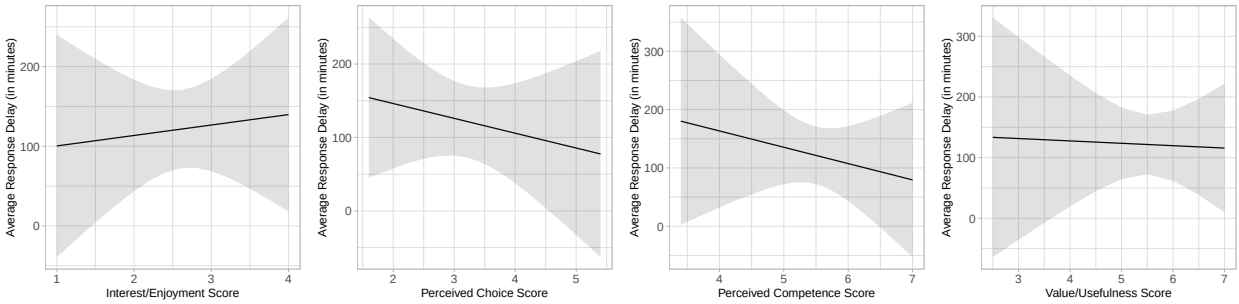
We found a statistically insignificant negative slope between perceived competence subscale scores and the average response delay for interventions about mental health, COVID-19, and diet & nutrition, as evident in Figures 34, 35, and 37. The only negative relationship with statistical significance was physical activity. With more data, these positive trends may become significant and support H4, that a higher perceived competence score for a topic should be associated with an decrease in the participant's average response delay for interventions about that topic.

For more details on the effects of all four IMI subscales on average response delay for the four intervention topics, please view Appendix Tables 25, 26, 27, and 28.



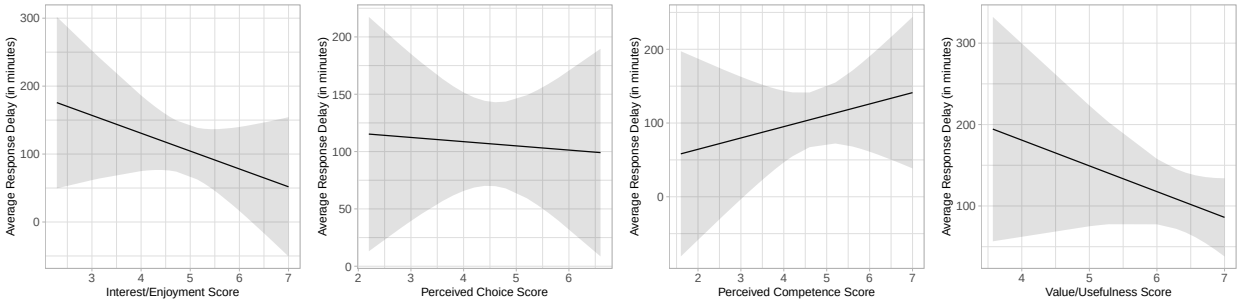
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 34: Effect of IMI subscale scores on average response delay for mental health interventions



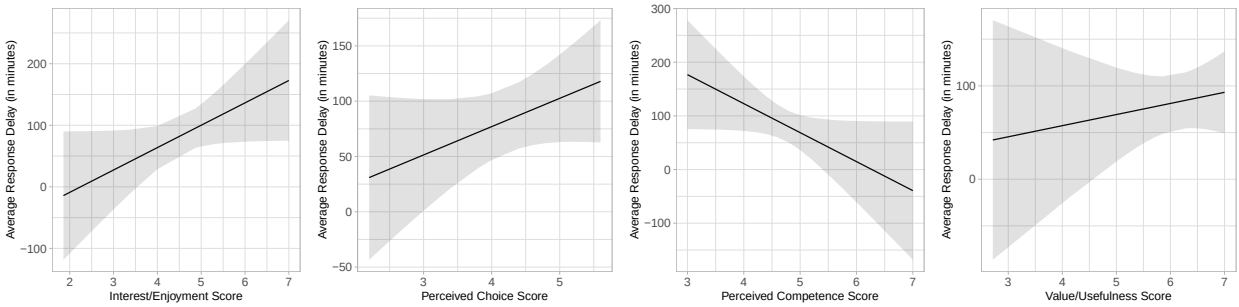
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 35: Effect of IMI subscale scores on average response delay for COVID-19 interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 36: Effect of IMI subscale scores on average response delay for physical activity interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 37: Effect of IMI subscale scores on average response delay for diet & nutrition interventions

6 Discussion

In this section, we summarize our findings and evaluate whether our results supported or failed to support our hypotheses. We also attempt to explain statistically significant results that countered our hypotheses, as well as any limitations that may have affected our results.

6.1 H1 and H2 – No Relationship Found Between Mean Intrinsic Motivation and Mean Receptivity Over a Given Time Period Across Topics

In our first two hypotheses, we predicted that a positive relationship exists between mean intrinsic motivation scores and mean receptivity metrics across topics. H1 specified that a higher intrinsic motivation score for an intervention topic compared to other topics would be associated with a higher average overall response rate to messages about that topic compared to other topics. H2 specified that a higher intrinsic motivation score for an intervention topic compared to other topics would be associated with a lower average response delay for messages about that topic compared to other topics.

In our across-topics analyses of mean receptivity metrics over a given period of time compared to mean intrinsic motivation measures, we found statistically significant pairwise differences in IMI subscale and total IMI scores across topics. However we were not able to find statistically significant pairwise differences in overall response rate, just-in-time response rate, and average response delay. This lack of statistically significant differences in receptivity metrics failed to support H1 and H2's claim that a positive relationship exists between intrinsic motivation scores and receptivity across topics.

The one receptivity metric for which we found statistically significant pairwise differences was conversation engagement. The pairwise comparisons included COVID-19 – diet & nutrition, and COVID-19 – physical activity, with positive estimates statistically significant at $p < .05$. The same pairwise differences had statistically significant negative estimates for interest/enjoyment, perceived choice, value/usefulness, and total IMI scores. Because the pairwise difference estimates were in opposing directions, this result failed to support the hypothesized positive relationship between intrinsic motivation scores and conversation engagement across topics.

The statistically significant negative pairwise differences between COVID-19 – diet & nutrition, and COVID-19 – physical activity for interest/enjoyment, perceived choice, value/usefulness, and total IMI scores suggested that participants (on average) perceived following COVID-19 guidelines as less enjoyable, less autonomous, less valuable, and less intrinsically motivated than eating well and maintaining a good diet, or keeping a physical activity routine. This observation might be explained by participants' fatigue from following COVID-19 guidelines during a prolonged pandemic. This study was conducted from the start of April until the end of May 2021, as vaccinations became readily distributed around the United States, and the CDC began relaxing social gathering and mask-wearing guidelines. As COVID-19 guidelines and risks from infection decreased over the course of the study, participants may have found COVID-19 guidelines less interesting or useful compared to other topics. The mean COVID-19 perceived choice score being lower than the mean perceived choice score for diet & nutrition and physical activity may be attributed to our participants being Dartmouth College students. 45% of our participants lived on-campus during the study, and were required to follow college COVID-19 guidelines to retain on-campus privileges. They were not required by the college to maintain a good diet or physical activity routine, perhaps contributing to mean perceived choice scores for diet & nutrition and physical activity being higher than mean perceived choice scores for COVID-19.

In contrast, the statistically significant negative pairwise differences between COVID-19 – diet & nutrition, and COVID-19 – physical activity showed that participants had (on average) higher around 14% higher conversation engagement with COVID-19 interventions than diet & nutrition or physical activity interventions. One possible explanation for the higher conversation engagement with COVID-19 interventions is the

saliency of the COVID-19 topic. Even if participants did not feel intrinsically motivated to follow COVID-19 guidelines compared to other topics, because of the importance of COVID-19 in participants' lives, they engaged more with COVID-19 interventions.

6.2 H3 and H4 – Positive Relationships Found Between Intrinsic Motivation and Receptivity Within Topics

In our third and fourth hypotheses, we argued that a positive relationship should exist between intrinsic motivation scores and receptivity within topics.

H3 specifically stated that a higher intrinsic motivation score should be associated with a higher likelihood of response for initiating messages about that topic. We found several instances of statistically significant positive relationships between intrinsic motivation scores and metrics related to response. For mental health, we found a one-point increase in the perceived choice score was associated with an 11.4% increase in the log-likelihood of response ($p < .001$). We also found that a one-point increase in the value/usefulness score corresponded with a 6.83% increase in the log-likelihood of response to mental health interventions ($p < .05$).

Similarly, for mental health we found a one-point increase in the perceived choice score was associated with an increase in the overall response rate over a time period by 11.03% ($p < .05$). An increase in the value/usefulness score was associated with a 8.02% increase in the overall response rate for mental health interventions ($p < .05$). For physical activity interventions, we discovered that a one-point increase in the value/usefulness score corresponded with a 13.47% increase in overall response rate ($p < .05$). Regarding diet & nutrition interventions, a one-point increase in the value/usefulness score was associated with an increase in overall response rate of 15.01% ($p < .05$).

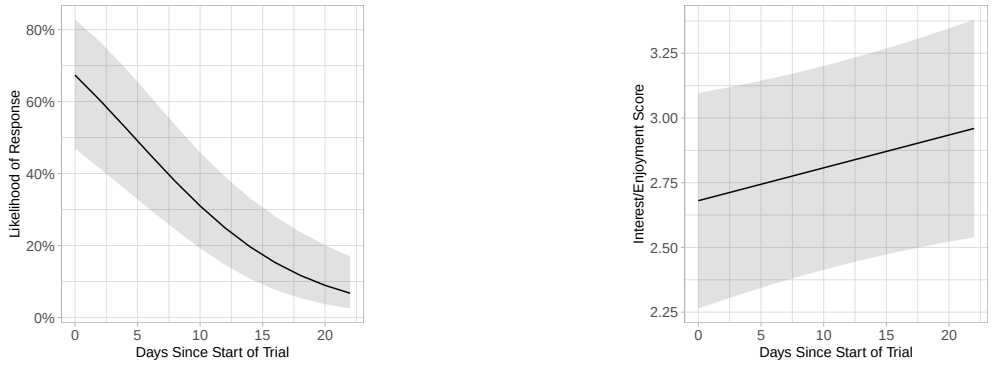
These statistically significant positive relationships found between perceived choice scores, value/usefulness scores and response metrics provided support for H3. In addition, we found statistically insignificant positive trends for value/usefulness scores and the likelihood of response, likelihood of just-in-time response, likelihood of conversation engagement, overall response rate, just-in-time response rate, and conversation rate for at least three of the four intervention topics. This consistent trend with our small sample size suggests that the value/usefulness scale may be a viable subscale to include in future studies. The value/usefulness subscale relates to the SDT concept of internalization, that people who take in the value of a behavior are more likely to self-regulate that behavior. It also supports previous research findings on phone notifications that people are more likely to respond to notifications whose content they view as useful [16].

H4 specifies that a higher intrinsic motivation score should correspond to a lower response delay for interventions about that topic. We found that for diet & nutrition interventions, a one-point increase in perceived competence score led to a decrease in the average response delay by 54.05 minutes ($p < .05$). This finding supported H4's predicted negative relationship between intrinsic motivation and response delay.

6.3 H3 and H4 – Negative Relationships Found Between Intrinsic Motivation and Receptivity Within Topics

We found a couple of statistically significant negative relationships between intrinsic motivation scores and response metrics. For COVID-19, we found a one-point increase in the interest/enjoyment score was associated with a decrease in the log-likelihood of response by 10.5% ($p < .05$). Similarly, a one-point increase in interest/enjoyment scores was associated with a 12.69% decrease in the overall response rate towards COVID-19 interventions ($p < .05$).

One possible explanation for the negative relationship between interest/enjoyment scores and the log likelihood of response is that our model did not take into account the temporal dynamics of interest/enjoyment scores and likelihood of response to COVID-19 interventions over the course of the study. The change in



(a) Likelihood of response to COVID-19 interventions over the course of the study

(b) COVID-19 interest/enjoyment scores over the course of the study

Figure 38: Temporal dynamics for COVID-19 interest/enjoyment score and likelihood of response

mean likelihood of response over days since the start of the trial was shown to have a statistically significant decrease in Figure 38a, with the shaded region for the 95% confidence interval. The mean interest/enjoyment score was shown in Figure 38b to have increased slightly over the course of the trial, with the the shaded region representing the 95% confidence interval.

As evident in Figure 38a, the log likelihood of response had a statistically significant decrease from a mean of 67.4% to 7.8%. The Elena+ COVID-19 intervention content was meant for a global audience, so it contained generic versions of the World Health Organization's COVID-19 guidelines. Because our study began in early April 2021 as the United States rolled out vaccinations and loosened CDC guidelines, participants may have found the (outdated) COVID-19 intervention content less interesting or useful, becoming less likely to respond as the trial continued.

Because Figure 38b shows the mean interest/enjoyment score only increased from 2.68 to 2.95, it's possible that the increase in interest/enjoyment for COVID-19 does not fully explain the negative relationship with likelihood of response. More causal studies are needed to find out the extent to which interest/enjoyment scores contribute to the negative relationship with likelihood of response.

We also found statistically insignificant negative trends for interest/enjoyment scores and the likelihood of response, likelihood of just-in-time response, likelihood of conversation engagement, overall response rate, just-in-time response rate, and conversation rate for at least three of the four intervention topics. This consistent trend with our small sample size suggests that the there may be a disconnect between the interest/enjoyment for the topics measured by the IMIs and the interest/enjoyment participants had for the Elena+ interventions.

When participants were asked in the post-study survey if "the content and messaging with Elena was interesting and engaging," 19.05% of participants selected "Strongly disagree," and 38.10% selected "Disagree," showing that a majority of participants did not find the interventions interesting. 33.33% of participants selected "Strongly agree" and 9.52% selected "Agree" when asked whether "for all types of notifications, the content of the notification was important while deciding if you want to respond to the notification." This suggests that while participants may have expressed high interest in the underlying intervention topics, a majority were disinterested in the intervention content, possibly influencing participants' response and engagement with interventions.

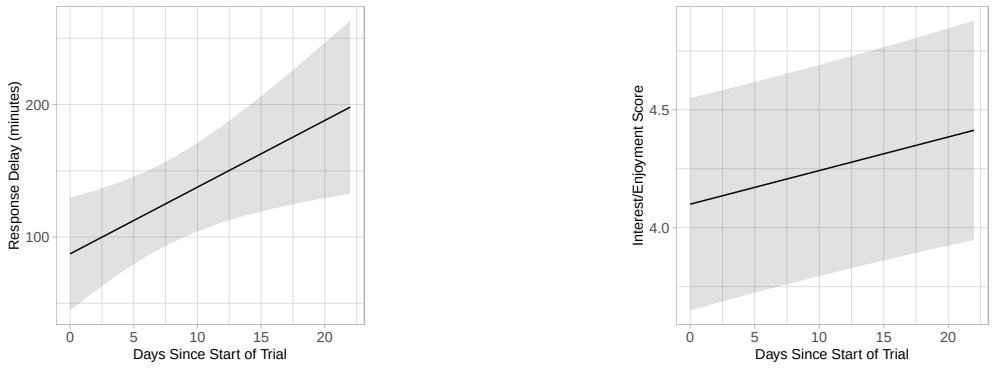
There may also have been other context factors that outweighed any interest/enjoyment participants had for that topic. 14.29% of participants selected "Strongly disagree" and 52.38% of participants selected "Disagree" for the statement that "the notifications from Elena were generated at times I was not busy with anything else," showing that a majority of participants were engaged in some activity when receiving

initiating messages. The timing of interventions when participants were engaged with some activity may have decreased the likelihood of response and just-in-time response, as 33.33% of participants selected "Strongly agree" and 38.10% selected "Agree" when asked whether they "responded to notifications with Elena only when I was free or not doing anything else." Delivery when participants were busy may have also decreased the likelihood of conversation engagement, as 42.86% of participants selected "Strongly agree" and 25.57% selected "Agree" when asked whether they "engaged in chat-conversations with Elena only when I was free or not doing anything else."

In our analysis, we found a few examples of a statistically significant positive relationship between intrinsic motivation scores and response delay or average response delay. For mental health, we found a one point increase in interest/enjoyment score was associated with an increase in response delay by 31.01 minutes $(p < .05)$. Similarly, a one point increase in interest/enjoyment score corresponded to an increase of 40.54 minutes in average response delay for mental health interventions $(p < .01)$. For diet & nutrition interventions, we found a one-point increase in interest/enjoyment was associated with an increase in average response delay by 36.55 minutes $(p < .05)$.

One possible explanation for the statistically significant positive relationship between interest/enjoyment scores and response delay for mental health is that our model did not take into account the temporal dynamics of interest/enjoyment scores and response delay to mental health interventions over the course of the study. The response delay was shown to have a statistically significant increase from 87.29 minutes to 193.02 minutes over the course of the trial in Figure 39a, with the shaded region for the 95% confidence interval. The mean interest/enjoyment score was shown in Figure 39b to have increased slightly from 2.68 to 2.95 over the course of the trial, with the the shaded region representing the 95% confidence interval.

Perhaps participants' interest/enjoyment for working on improving their mental health stayed constant or increased, however their interest/enjoyment for the mental health interventions decreased over the course of the study. We speculate that a possible decrease in interest/enjoyment or value/usefulness for the interventions could explain the increase in response delay and average response delay over the course of the study. In future studies, the IMIs could be changed to be about the interventions instead of the underlying health goals the interventions are trying to promote. Such a change in study design would allow researchers to determine the relationship between interest/enjoyment for the intervention and receptivity toward such interventions.



(a) Response delay to mental health interventions over the course of the study

(b) Mental health interest/enjoyment scores over the course of the study

Figure 39: Temporal dynamics for mental health interest/enjoyment score and response delay

6.4 Limitations

One limitation of our work was the small sample size of 20 participants. All our participants were Dartmouth students, who may be more homogeneous than the general population. Dartmouth students may have similar intrinsic motivation levels for various topics due to campus culture or similar backgrounds. The general population likely has greater variation in intrinsic motivation both within and across topics. Thus the magnitude of the relationships we found between intrinsic motivation and receptivity could be understated compared to what might be found with a more diverse set of participants.

Another limitation of our study was that we did not create IMIs about the interventions themselves. As discussed in the previous section, there may be disconnect between the interest/enjoyment participants have for the underlying topic of interventions compared to the interest/enjoyment for the related interventions themselves.

A third limitation of our study could be the inclusion of COVID-19 as a topic. The relationships found between intrinsic motivation and receptivity for COVID-19 interventions often were in the opposite direction than expected. The topic saliency of COVID-19 may have affected participants' IMI survey responses and receptivity to COVID-19 interventions. In addition, the COVID-19 situation changed during the course of the study, with vaccinations ramping up in New Hampshire and across the country, and COVID-19 guidelines being rolled back. The evolving nature of the COVID-19 situation may have affected participants' intrinsic motivation toward following COVID-19 guidelines, and affected participants' receptivity towards COVID-19 interventions.

7 Summary and Conclusion

In this study, we examined whether across-topic and within-topic relationships exist between measures of intrinsic motivation for the underlying mHealth intervention topics and receptivity metrics. We conducted a study with 20 participants over 3 weeks at Dartmouth College. At a random time during three daily intervals, participants received an mHealth intervention about one of four topics: mental health, COVID-19, physical activity, and diet & nutrition. To deliver our interventions, we deployed a modified version of the Elena+ iOS app [19] and the MobileCoach platform [6, 11]. We measured receptivity in-the-moment using response, just-in-time response, conversation engagement, and response delay, as well as receptivity over a given period of time using response rate, just-in-time response rate, conversation rate, and average response delay.

Our exploratory analysis found that significant differences in mean intrinsic motivation scores across topics were not associated with differences in mean receptivity metrics across topics. We also found that positive relationships exist between intrinsic motivation measures and likelihood of response for interventions about a topic.

The lack of relationship between mean intrinsic motivation scores and mean receptivity metrics across topics suggests that differences in intrinsic motivation across various topics should not be used by JITAIs to choose what intervention topic to deliver to recipients. In general, recipients will be similarly receptive across topics.

The existence of a positive relationship between intrinsic motivation measures and receptivity for interventions about a single topic suggest the potential for JITAIs that incorporate techniques to monitor and improve intrinsic motivation. Intrinsic motivation can be enhanced by goal-setting, motivational interviewing, and supporting a recipient's sense of autonomy, competence or relatedness for a behavior. Self-regulation of behaviors can be promoted through internalization, the taking in of the value of a behavior. Since we found both significant and insignificant positive relationships between value/usefulness IMI subscale scores and receptivity, future researchers could periodically assess participants' personal values and the value they assign to the intervention. This information could then be used to tailor intervention content to better align

the value of a behavior with the participants' own values, possibly contributing to an increase in response to interventions.

A Appendix

Table 13: Intrinsic Motivation Inventory items about mental health

Subscale	Item
Perceived Choice	I feel it is my choice to work on improving my mental health
Perceived Competence	I am satisfied with my performance at working on improving my mental health
Perceived Competence	I think I am pretty good at working on improving my mental health
Interest/Enjoyment	I find mental health information very interesting
Value/Usefulness	I think working on improving my mental health is an important activity
Perceived Competence	I think I do pretty well at working on improving my mental health, compared to my peers
Interest/Enjoyment	Working on improving my mental health is fun
Value/Usefulness	I believe working on improving my mental health could be beneficial to me
Interest/Enjoyment	When I work on improving my mental health, I think about how much I enjoy it
Interest/Enjoyment	I enjoy working on improving my mental health very much
Perceived Choice	I don't really have a choice about working on improving my mental health
Interest/Enjoyment	I think mental health information is very boring
Value/Usefulness	I think working on improving my mental health could help me
Value/Usefulness	I think that working on improving my mental health is useful
Perceived Competence	I feel pretty skilled at improving my mental health
Value/Usefulness	I believe improving my mental health could be of some value to me
Perceived Competence	After working on improving my mental health for awhile, I felt pretty competent
Interest/Enjoyment	I think mental health information is very interesting
Perceived Choice	I feel like I have to improve my mental health
Interest/Enjoyment	I would describe improving my mental health as very enjoyable
Value/Usefulness	I would be willing to work on improving my mental health again because it has some value to me
Value/Usefulness	I think improving my mental health is important to do
Perceived Choice	I work on improving my mental health because I have no choice
Perceived Choice	I feel like I am doing what I want to do when I do work on improving my mental health

Table 14: Intrinsic Motivation Inventory items about COVID-19 guidelines

Subscale	Item
Interest/Enjoyment	When I follow COVID-19 guidelines, I think about how much I enjoy it
Perceived Choice	I feel it is my choice to follow COVID-19 guidelines
Value/Usefulness	I think following COVID-19 guidelines is an important activity
Perceived Competence	I think I am pretty good at following COVID-19 guidelines
Interest/Enjoyment	I find COVID-19 health information very interesting
Perceived Competence	I think I do pretty well at following COVID-19 guidelines, compared to my peers
Interest/Enjoyment	Following COVID-19 guidelines is fun
Interest/Enjoyment	I enjoy following COVID-19 guidelines very much
Perceived Choice	I don't really have a choice about following COVID-19 guidelines
Perceived Competence	I am satisfied with my performance at following COVID-19 guidelines
Interest/Enjoyment	I think COVID-19 health information is very boring
Perceived Choice	I feel like I am doing what I want to do when I follow COVID-19 guidelines
Value/Usefulness	I think following COVID-19 guidelines could help me
Value/Usefulness	I believe following COVID-19 guidelines could be beneficial to me
Perceived Competence	I feel pretty skilled at following COVID-19 guidelines
Value/Usefulness	I believe following COVID-19 guidelines could be of some value to me
Interest/Enjoyment	I think COVID-19 health information is very interesting
Perceived Choice	I feel like I have to follow COVID-19 guidelines
Interest/Enjoyment	I would describe following COVID-19 guidelines as very enjoyable
Value/Usefulness	I think following COVID-19 guidelines is important to do
Perceived Choice	I follow COVID-19 guidelines because I have no choice
Perceived Competence	After following COVID-19 guidelines for awhile, I felt pretty competent
Value/Usefulness	I think that following COVID-19 guidelines is useful
Value/Usefulness	I would be willing to follow COVID-19 guidelines again because it has some value to me

Table 15: Intrinsic Motivation Inventory items about physical activity

Subscale	Item
Perceived Competence	I think I am pretty good at keeping a physical activity routine
Interest/Enjoyment	I find physical activity very interesting
Perceived Choice	I feel it is my choice to do physical activity
Interest/Enjoyment	I enjoy doing physical activity very much
Perceived Choice	I don't really have a choice about doing physical activity
Interest/Enjoyment	When I do physical activity, I think about how much I enjoy it
Perceived Competence	I am satisfied with my performance at maintaining a physical activity routine
Interest/Enjoyment	I think physical activity is very boring
Perceived Choice	I feel like I am doing what I want to do when I do physical activity
Value/Usefulness	I think doing physical activity could help me
Perceived Competence	I think I do pretty well at physical activity, compared to my peers
Interest/Enjoyment	Doing physical activity is fun
Perceived Choice	I do physical activity because I have no choice
Value/Usefulness	I think physical activity is an important activity
Value/Usefulness	I believe doing physical activity could be beneficial to me
Perceived Competence	After doing physical activity for awhile, I felt pretty competent
Value/Usefulness	I think that doing physical activity is useful
Value/Usefulness	I believe physical activity could be of some value to me
Interest/Enjoyment	I think physical activity is very interesting
Perceived Choice	I feel like I have to do physical activity
Value/Usefulness	I would be willing to do physical activity again because it has some value to me
Perceived Competence	I feel pretty skilled at physical activity
Interest/Enjoyment	I would describe physical activity as very enjoyable
Value/Usefulness	I think physical activity is important to do

Table 16: Intrinsic Motivation Inventory items about diet & nutrition

Subscale	Item
Perceived Choice	I feel it is my choice to eat well and maintain a good diet
Value/Usefulness	I think eating well and maintaining a good diet is an important activity
Interest/Enjoyment	When I eat well and maintain a good diet, I think about how much I enjoy it
Perceived Competence	I think I am pretty good at eating well and maintaining a good diet
Interest/Enjoyment	I find diet and nutrition information very interesting
Interest/Enjoyment	Eating well and maintaining a good diet is fun
Perceived Competence	I think I do pretty well at maintaining a good diet, compared to my peers
Interest/Enjoyment	I enjoy eating well and maintaining a good diet very much
Perceived Choice	I don't really have a choice about eating well and maintaining a good diet
Interest/Enjoyment	I think diet and nutrition information is very boring
Perceived Choice	I feel like I am doing what I want to do when I eat well and maintain a good diet
Perceived Competence	I am satisfied with my performance at eating well and maintaining a good diet
Value/Usefulness	I think eating well and maintaining a good diet could help me
Value/Usefulness	I believe eating well and maintaining a good diet could be beneficial to me
Perceived Competence	I feel pretty skilled at eating well and maintaining a good diet
Value/Usefulness	I believe eating well and maintaining a good diet could be of some value to me
Perceived Competence	After eating well and maintaining a good diet for awhile, I felt pretty competent
Interest/Enjoyment	I think diet and nutrition information is very interesting
Perceived Choice	I feel like I have to eat well and maintain a good diet
Value/Usefulness	I think eating well and maintaining a good diet is important to do
Interest/Enjoyment	I would describe eating well and maintaining a good diet as very enjoyable
Value/Usefulness	I would be willing to eat well and maintain a good diet again because it has some value to me
Perceived Choice	I eat well and maintain a good diet because I have no choice
Value/Usefulness	I think that eating well and maintaining a good diet is useful

Figure 40: The Elena+ app can deliver 43 unique coaching sessions about loneliness, anxiety, mental resources, diet & nutrition, COVID-19, physical activity, and sleep.

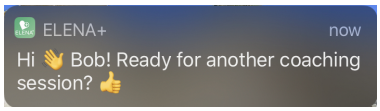


Figure 41: Example of a generic push notification from Elena+. When a participant tapped the notification, they were navigated to the Elena+ app to view an initiating message.

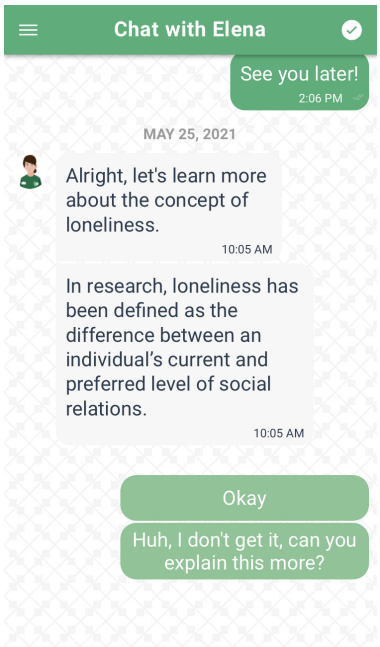


Figure 42: Example of an initiating message. An initiating message is the first message in an intervention that requires the participant to reply by selecting from provided answer options. Whether or not the participant replied, and when the participant replied was used to calculate receptivity metrics.

Table 17: Effect of IMI subscale scores on receptivity in-the-moment for mental health interventions

	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	-5.19^{**}	-2.27	-0.46	-71.37
	(1.67)	(2.18)	(3.25)	(114.52)
Interest/Enjoyment	-0.21	-0.23	-0.35	31.01^{*}
	(0.25)	(0.36)	(0.54)	(15.82)
Perceived Choice	0.72^{***}	0.13	-0.03	6.75
	(0.20)	(0.28)	(0.45)	(15.54)
Perceived Competence	-0.17	-0.18	0.41	7.27
	(0.21)	(0.26)	(0.41)	(12.77)
Value/Usefulness	0.43^{*}	0.05	0.18	0.83
	(0.18)	(0.22)	(0.41)	(14.04)
AIC	664.89	328.13	75.16	2542.60
BIC	692.13	355.37	86.63	2565.62
Log Likelihood	-326.45	-158.07	-31.58	-1264.30
Num. obs.	692	692	50	198
Num. groups: uid	20	20	20	20
Var: uid (Intercept)	2.95	1.58	0.87	638.18
Var: Residual				24665.74

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 18: Effect of IMI subscale scores on receptivity in-the-moment for COVID-19 interventions

	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	-0.71	-1.64	-1.24	276.79^{*}
	(1.64)	(1.76)	(2.03)	(127.92)
Interest/Enjoyment	-0.78^{*}	-0.21	-0.31	0.69
	(0.31)	(0.32)	(0.34)	(31.09)
Perceived Choice	-0.32	-0.50	-0.37	-8.89
	(0.26)	(0.30)	(0.44)	(22.14)
Perceived Competence	0.17	-0.27	0.32	19.25
	(0.37)	(0.40)	(0.47)	(33.35)
Value/Usefulness	0.43	0.54	0.35	-43.29
	(0.32)	(0.30)	(0.41)	(26.11)
AIC	254.74	135.93	78.69	935.87
BIC	274.82	156.01	90.63	952.09
Log Likelihood	-121.37	-61.96	-33.35	-460.94
Num. obs.	210	210	54	75
Num. groups: uid	20	20	20	19
Var: uid (Intercept)	0.84	0.00	0.04	1104.07
Var: Residual				22434.93

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 19: Effect of IMI subscale scores on receptivity in-the-moment for physical activity interventions

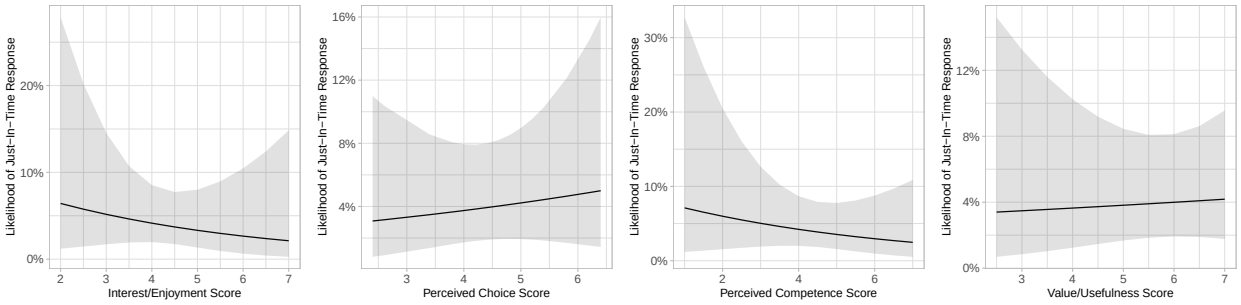
	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	−4.46	−11.33	−1.81	357.29
	(2.72)	(7.06)	(4.49)	(213.28)
Interest/Enjoyment	0.20	−0.81	−0.43	−46.99
	(0.45)	(0.87)	(0.82)	(30.90)
Perceived Choice	0.03	−0.37	−0.30	12.57
	(0.40)	(0.72)	(0.69)	(26.30)
Perceived Competence	−0.18	1.06	0.19	32.17
	(0.39)	(0.92)	(0.73)	(31.28)
Value/Usefulness	0.45	1.16	0.47	−33.09
	(0.32)	(1.01)	(0.58)	(33.12)
AIC	189.90	80.23	69.97	569.88
BIC	209.16	99.49	81.90	582.83
Log Likelihood	−88.95	−34.12	−28.98	−277.94
Num. obs.	183	183	54	47
Num. groups: uid	20	20	20	17
Var: uid (Intercept)	2.85	4.83	5.91	0.00
Var: Residual				21520.80

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 20: Effect of IMI subscale scores on receptivity in-the-moment for diet & nutrition interventions

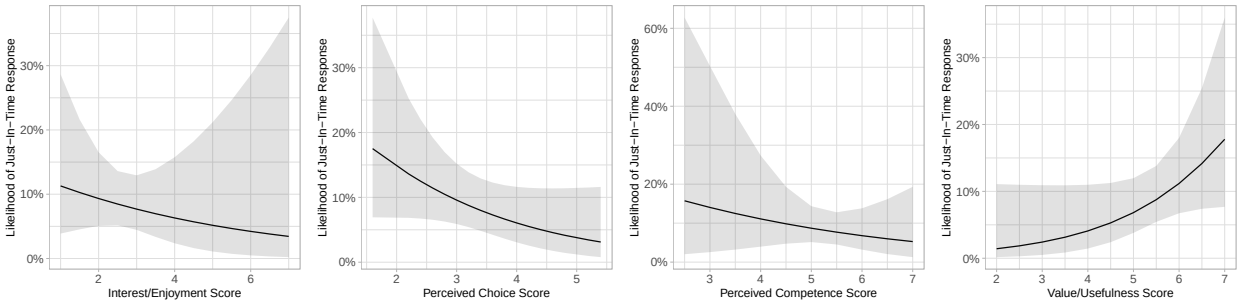
	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	−0.36	−0.82	0.41	−45.62
	(2.04)	(2.10)	(1.93)	(84.67)
Interest/Enjoyment	−0.37	−0.37	−0.41	19.30
	(0.38)	(0.38)	(0.36)	(16.97)
Perceived Choice	−0.23	−0.12	−0.02	36.49
	(0.36)	(0.37)	(0.34)	(18.63)
Perceived Competence	0.33	0.37	0.35	−21.64
	(0.40)	(0.47)	(0.43)	(23.71)
Value/Usefulness	0.05	−0.19	−0.12	−2.14
	(0.34)	(0.32)	(0.33)	(16.76)
AIC	167.05	93.05	73.34	405.42
BIC	185.15	111.15	84.69	416.69
Log Likelihood	−77.52	−40.52	−30.67	−195.71
Num. obs.	151	151	49	37
Num. groups: uid	20	20	20	16
Var: uid (Intercept)	1.45	0.12	0.00	0.00
Var: Residual				7035.98

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$



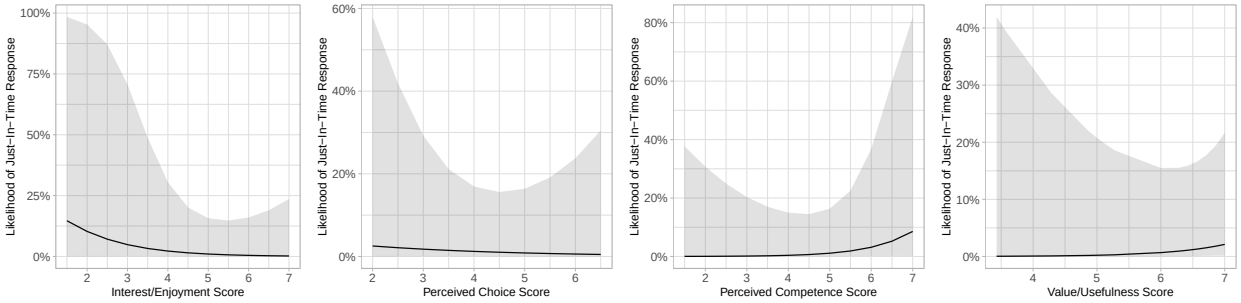
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 43: Effect of IMI subscale scores on likelihood of just-in-time response to mental health interventions



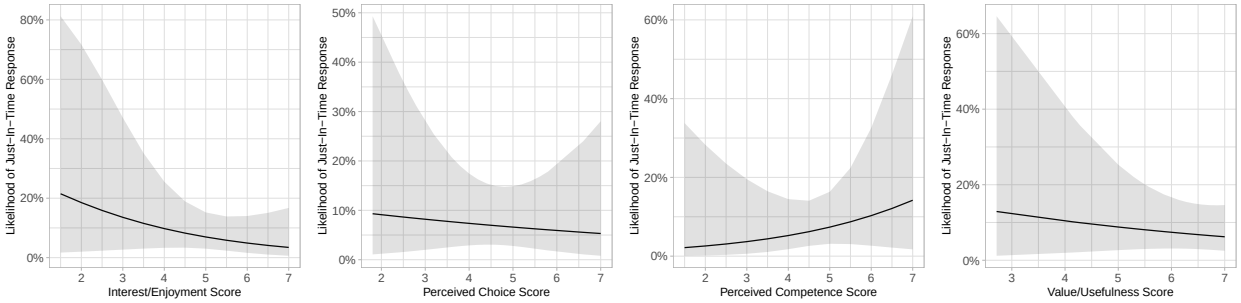
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 44: Effect of IMI subscale scores on likelihood of just-in-time response to COVID-19 interventions



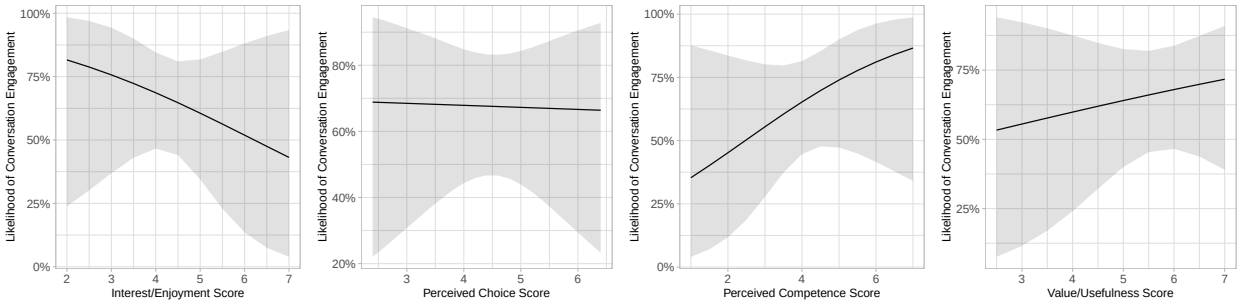
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 45: Effect of IMI subscale scores on likelihood of just-in-time response to physical activity interventions



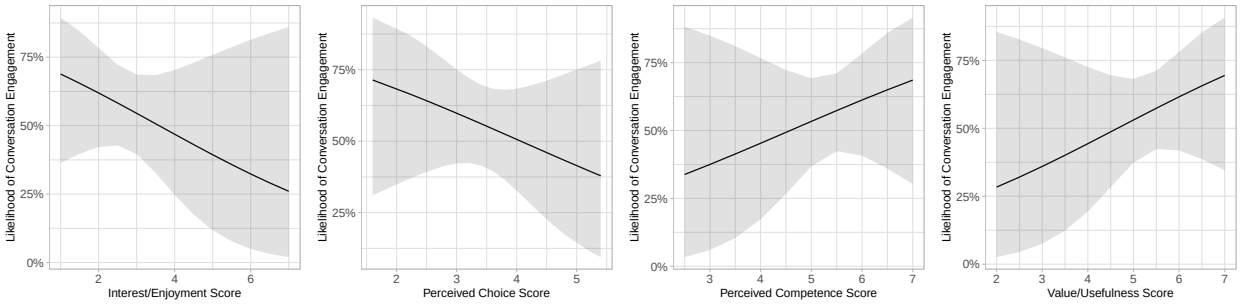
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 46: Effect of IMI subscale scores on likelihood of just-in-time response to diet & nutrition interventions



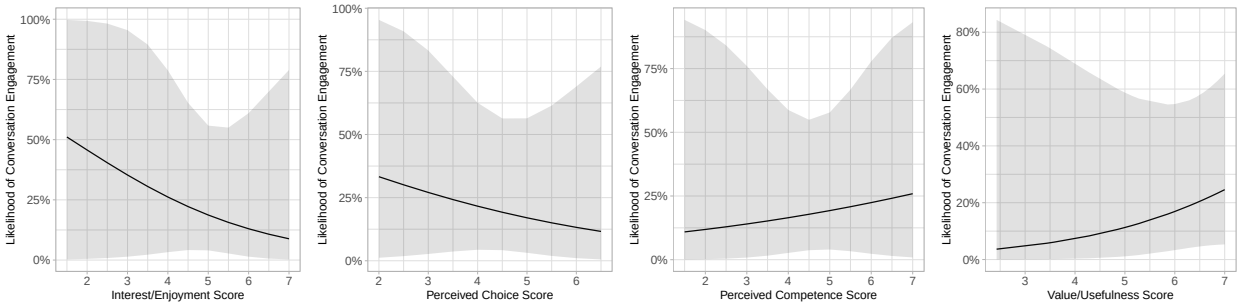
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 47: Effect of IMI subscale scores on likelihood of conversation engagement with mental health interventions



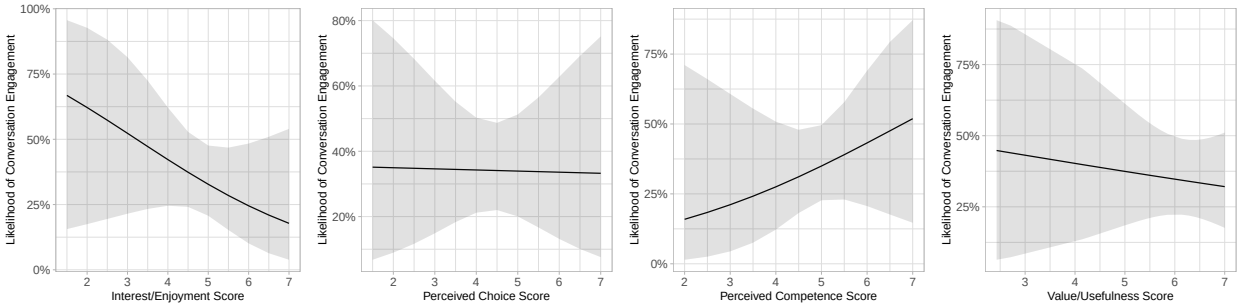
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 48: Effect of IMI subscale scores on likelihood of conversation engagement with COVID-19 interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 49: Effect of IMI subscale scores on likelihood of conversation engagement with physical activity interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 50: Effect of IMI subscale scores on likelihood of conversation engagement with diet & nutrition interventions

Table 21: Effect of total IMI scores on receptivity in-the-moment for mental health interventions

	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	-3.66^{*}	-1.29	-0.72	-112.75
	(1.63)	(2.15)	(3.02)	(89.70)
Total IMI Score	0.14	-0.10	0.10	12.39^{**}
	(0.08)	(0.11)	(0.16)	(4.68)
AIC	671.04	322.75	73.87	2561.57
BIC	684.66	336.36	80.05	2574.72
Log Likelihood	-332.52	-158.37	-33.93	-1276.78
Num. obs.	692	692	58	198
Num. groups: uid	20	20	20	20
Var: uid (Intercept)	3.40	1.85	3.30	949.64
Var: Residual				24315.22

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 22: Effect of total IMI scores on receptivity in-the-moment for COVID-19 interventions

	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	-0.87	-2.77^{*}	-1.52	333.74^{**}
	(1.39)	(1.35)	(1.65)	(118.39)
Total IMI Score	0.01	0.03	0.10	-13.00
	(0.08)	(0.08)	(0.10)	(7.01)
AIC	265.64	137.93	79.02	958.40
BIC	275.68	147.97	84.98	967.67
Log Likelihood	-129.82	-65.96	-36.51	-475.20
Num. obs.	210	210	54	75
Num. groups: uid	20	20	20	19
Var: uid (Intercept)	0.95	0.00	0.00	1436.62
Var: Residual				21708.25

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 23: Effect of total IMI scores on receptivity in-the-moment for physical activity interventions

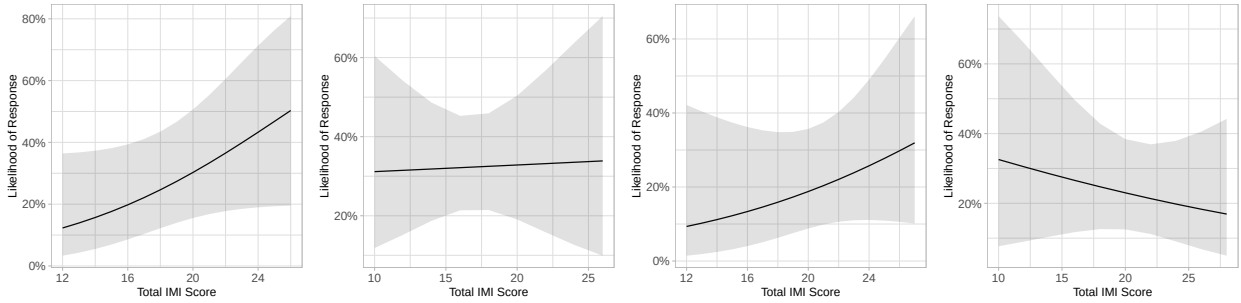
	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	−3.49	−7.93	−0.88	306.12*
	(2.13)	(4.58)	(3.46)	(145.70)
pa_imi_total	0.10	0.18	−0.03	−8.86
	(0.10)	(0.19)	(0.16)	(6.84)
AIC	185.94	77.57	65.26	594.74
BIC	195.57	87.20	71.23	602.14
Log Likelihood	−89.97	−35.79	−29.63	−293.37
Num. obs.	183	183	54	47
Num. groups: uid	20	20	20	17
Var: uid (Intercept)	2.75	3.95	5.85	0.00
Var: Residual				21568.37

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 24: Effect of total IMI scores on receptivity in-the-moment for diet & nutrition interventions

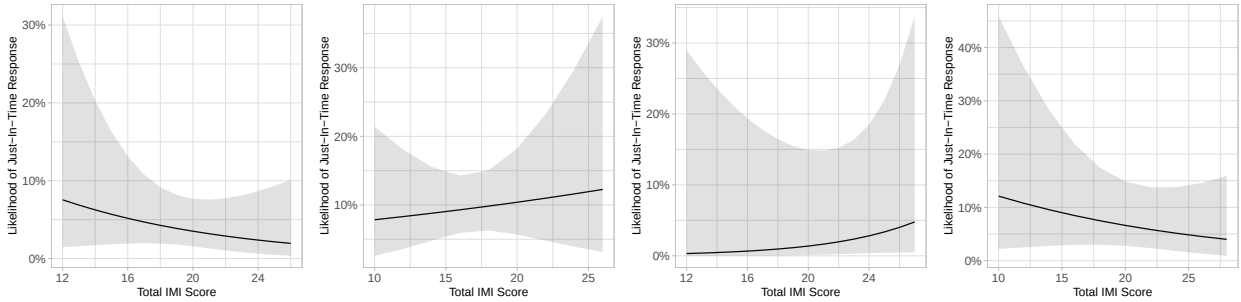
	Response	Just-in-time Response	Conversation Engagement	Response Delay (minutes)
(Intercept)	−0.25	−1.32	0.65	−44.46
	(1.64)	(1.66)	(1.45)	(70.02)
diet_imi_total	−0.05	−0.07	−0.06	6.45
	(0.08)	(0.08)	(0.07)	(3.49)
AIC	162.06	87.95	68.45	427.82
BIC	171.11	97.00	74.13	434.26
Log Likelihood	−78.03	−40.98	−31.23	−209.91
Num. obs.	151	151	49	37
Num. groups: uid	20	20	20	16
Var: uid (Intercept)	1.66	0.59	0.00	555.36
Var: Residual				6637.98

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$



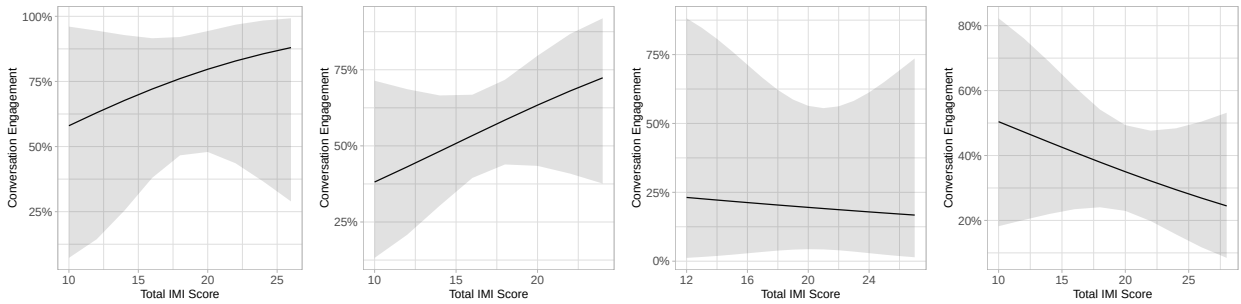
(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 51: Effect of total IMI scores on likelihood of response to intervention topics



(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 52: Effect of total IMI scores on likelihood of just-in-time response to intervention topics



(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 53: Effect of total IMI scores on likelihood of conversation engagement with intervention topics

Table 25: Effect of IMI subscale scores on receptivity over a given period for mental health interventions

	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	−0.05	0.17	0.00	−51.90
	(0.36)	(0.19)	(0.00)	(94.00)
Interest/Enjoyment	−0.07	−0.03	−0.00	40.54**
	(0.06)	(0.03)	(0.00)	(15.71)
Perceived Choice	0.11*	0.03	0.00	−4.06
	(0.05)	(0.03)	(0.00)	(13.77)
Perceived Competence	−0.06	−0.04	−0.00	−7.21
	(0.05)	(0.03)	(0.00)	(11.83)
Value/Usefulness	0.08*	0.02	0.00	9.76
	(0.04)	(0.02)	(0.00)	(11.47)
AIC	58.09	−6.54	−411.18	518.40
BIC	72.51	7.89	−396.75	531.35
Log Likelihood	−22.04	10.27	212.59	−252.20
Num. obs.	58	58	58	47
Num. groups: uid	20	20	20	20
Var: uid (Intercept)	0.07	0.02	0.00	0.00
Var: Residual	0.06	0.02	0.00	6136.14

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 26: Effect of IMI subscale scores on receptivity over a given period for COVID-19 interventions

	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	0.40	0.21	0.00	327.58
	(0.35)	(0.20)	(0.01)	(175.08)
Interest/Enjoyment	−0.13*	−0.01	−0.00	13.11
	(0.06)	(0.03)	(0.00)	(39.74)
Perceived Choice	−0.06	−0.05	−0.00	−20.20
	(0.06)	(0.04)	(0.00)	(29.67)
Perceived Competence	0.10	−0.02	0.00	−27.97
	(0.08)	(0.05)	(0.00)	(40.14)
Value/Usefulness	0.01	0.04	−0.00	−3.93
	(0.06)	(0.04)	(0.00)	(31.22)
AIC	69.95	21.15	−326.62	468.02
BIC	83.87	35.07	−312.69	479.66
Log Likelihood	−27.97	−3.57	170.31	−227.01
Num. obs.	54	54	54	39
Num. groups: uid	20	20	20	19
Var: uid (Intercept)	0.02	0.00	0.00	0.00
Var: Residual	0.11	0.05	0.00	22706.94

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 27: Effect of IMI subscale scores on receptivity over a given period for physical activity interventions

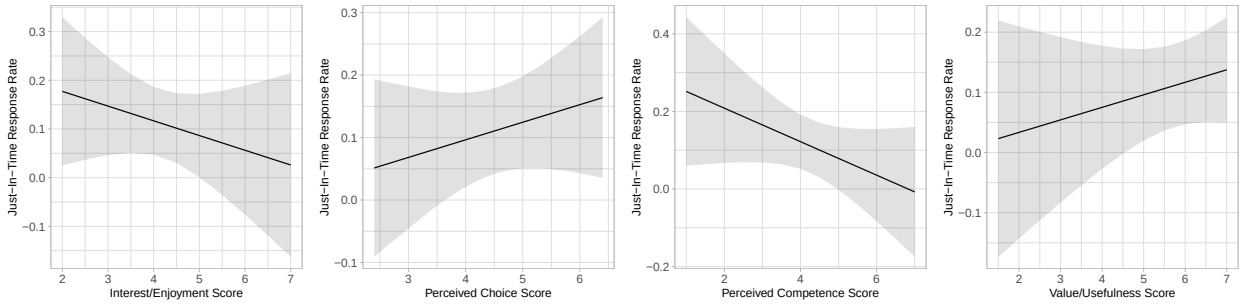
	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	0.05	−0.25	−0.00	380.30*
	(0.42)	(0.24)	(0.01)	(149.78)
Interest/Enjoyment	−0.08	−0.03	−0.00	−26.28
	(0.07)	(0.04)	(0.00)	(22.16)
Perceived Choice	−0.06	0.00	0.00	−3.67
	(0.06)	(0.04)	(0.00)	(19.55)
Perceived Competence	0.01	0.04	0.00	15.37
	(0.06)	(0.04)	(0.00)	(20.57)
Value/Usefulness	0.13**	0.04	0.00	−31.62
	(0.05)	(0.03)	(0.00)	(23.07)
AIC	64.40	17.21	−357.90	291.35
BIC	78.32	31.13	−343.98	300.42
Log Likelihood	−25.20	−1.60	185.95	−138.68
Num. obs.	54	54	54	27
Num. groups: uid	20	20	20	17
Var: uid (Intercept)	0.10	0.02	0.00	0.00
Var: Residual	0.06	0.03	0.00	8388.46

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 28: Effect of IMI subscale scores on receptivity over a given period for diet & nutrition interventions

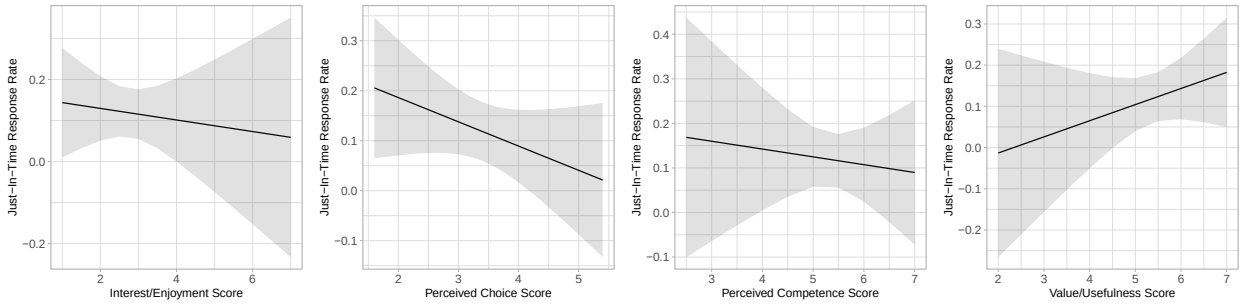
	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	−0.29	0.17	0.00	−5.87
	(0.36)	(0.24)	(0.00)	(96.26)
Interest/Enjoyment	−0.10	−0.04	−0.00	36.35*
	(0.07)	(0.04)	(0.00)	(18.10)
Perceived Choice	−0.01	0.01	−0.00	25.58
	(0.06)	(0.04)	(0.00)	(16.29)
Perceived Competence	0.04	0.03	0.00	−54.04*
	(0.07)	(0.05)	(0.00)	(26.77)
Value/Usefulness	0.15*	−0.01	0.00	11.92
	(0.06)	(0.04)	(0.00)	(17.70)
AIC	63.05	28.76	−305.72	268.54
BIC	76.29	42.00	−292.47	277.35
Log Likelihood	−24.53	−7.38	159.86	−127.27
Num. obs.	49	49	49	26
Num. groups: uid	20	20	20	16
Var: uid (Intercept)	0.10	0.01	0.00	0.00
Var: Residual	0.06	0.04	0.00	5162.10

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$



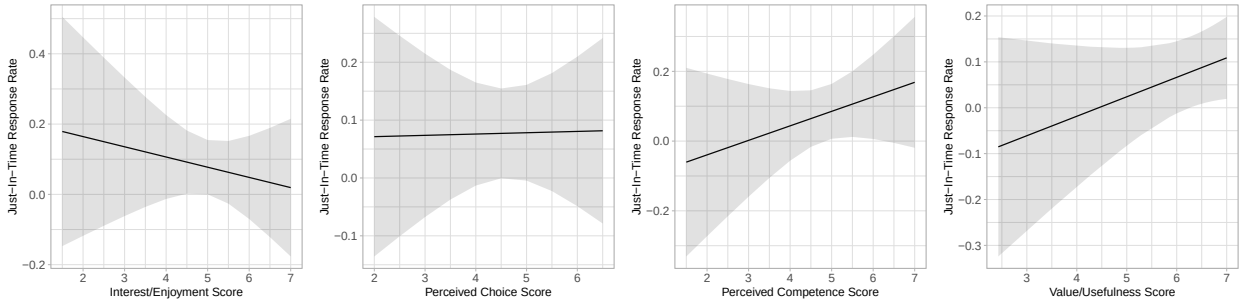
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 54: Effect of IMI subscale scores on just-in-time response rate for mental health interventions



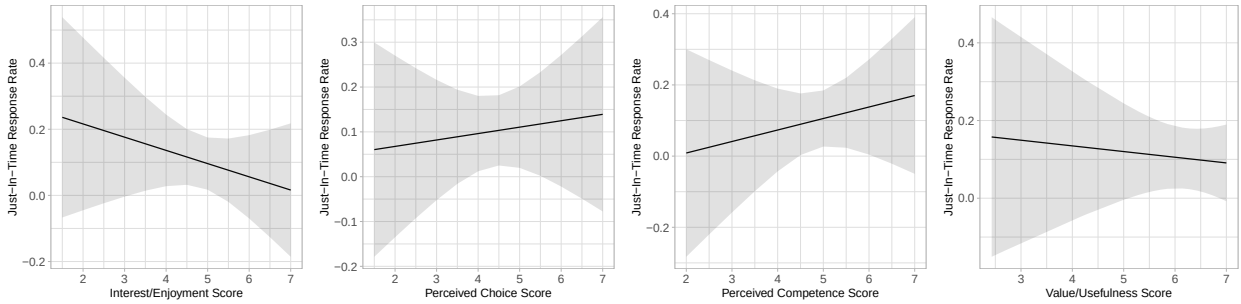
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 55: Effect of IMI subscale scores on just-in-time response rate for COVID-19 interventions



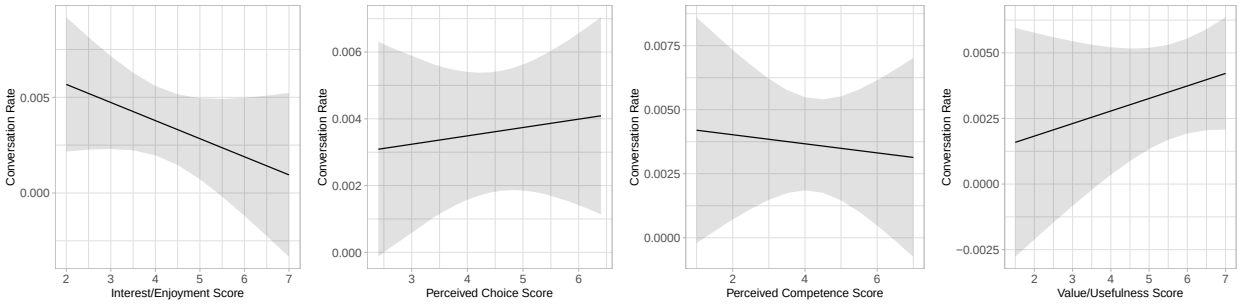
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 56: Effect of IMI subscale scores on just-in-time response rate for physical activity interventions



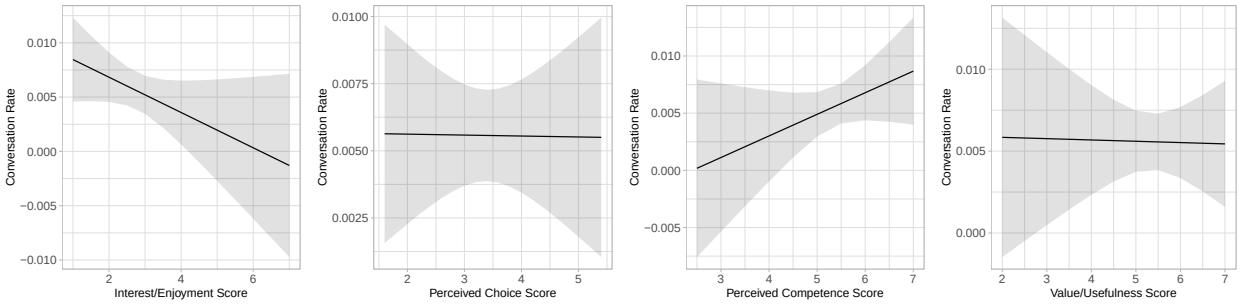
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 57: Effect of IMI subscale scores on just-in-time response rate for diet & nutrition interventions



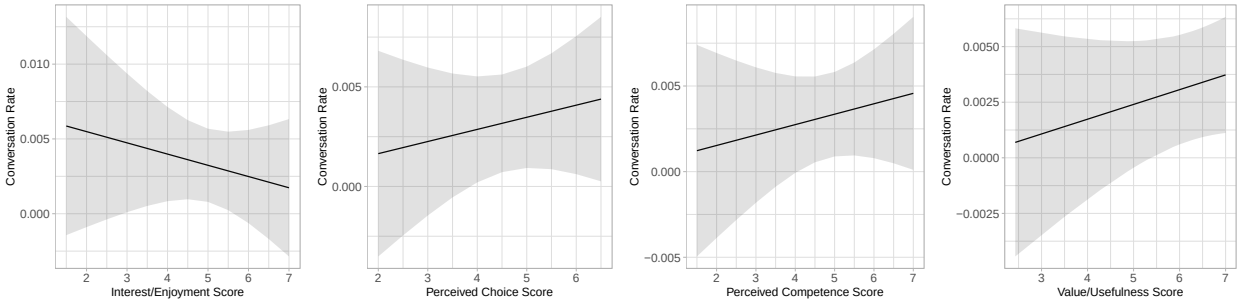
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 58: Effect of IMI subscale scores on conversation rate for mental health interventions



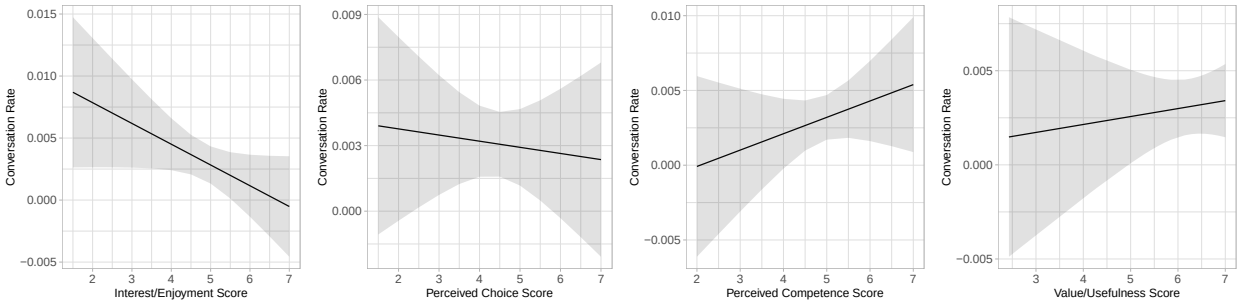
(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 59: Effect of IMI subscale scores on conversation rate for COVID-19 interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 60: Effect of IMI subscale scores on conversation rate for physical activity interventions



(a) Interest/Enjoyment (b) Perceived Choice (c) Perceived Competence (d) Value/Usefulness

Figure 61: Effect of IMI subscale scores on conversation rate for diet & nutrition interventions

Table 29: Effect of total IMI scores on receptivity over a given period for mental health interventions

	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	0.35	0.34*	0.00	−67.83
	(0.33)	(0.17)	(0.00)	(75.20)
total	0.00	−0.01	−0.00	10.14*
	(0.02)	(0.01)	(0.00)	(3.97)
AIC	49.91	−22.29	−451.76	540.36
BIC	58.15	−14.05	−443.52	547.76
Log Likelihood	−20.96	15.15	229.88	−266.18
Num. obs.	58	58	58	47
Num. groups: uid	20	20	20	20
Var: uid (Intercept)	0.06	0.02	0.00	38.28
Var: Residual	0.07	0.02	0.00	6422.07

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 30: Effect of total IMI scores on receptivity over a given period for COVID-19 interventions

	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	0.49	0.09	0.00	289.40
	(0.32)	(0.17)	(0.01)	(149.40)
total	−0.00	0.00	0.00	−9.96
	(0.02)	(0.01)	(0.00)	(8.76)
AIC	64.85	6.32	−360.42	490.99
BIC	72.81	14.27	−352.46	497.64
Log Likelihood	−28.43	0.84	184.21	−241.49
Num. obs.	54	54	54	39
Num. groups: uid	20	20	20	19
Var: uid (Intercept)	0.02	0.00	0.00	0.00
Var: Residual	0.13	0.05	0.00	21266.24

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 31: Effect of total IMI scores on receptivity over a given period for physical activity interventions

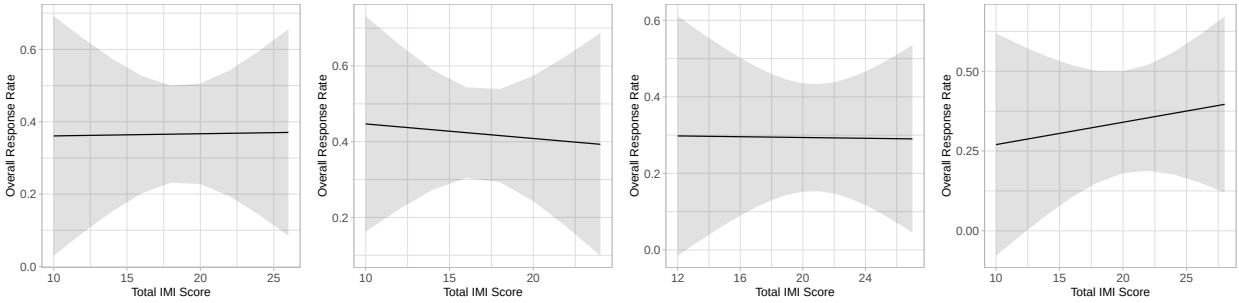
	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	0.30	−0.19	0.00	278.23**
	(0.34)	(0.19)	(0.00)	(97.39)
total	−0.00	0.01	0.00	−8.34
	(0.02)	(0.01)	(0.00)	(4.66)
AIC	57.66	0.46	−398.59	313.48
BIC	65.62	8.42	−390.63	318.66
Log Likelihood	−24.83	3.77	203.29	−152.74
Num. obs.	54	54	54	27
Num. groups: uid	20	20	20	17
Var: uid (Intercept)	0.07	0.02	0.00	0.00
Var: Residual	0.08	0.03	0.00	8200.92

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 32: Effect of total IMI scores on receptivity over a given period for diet & nutrition interventions

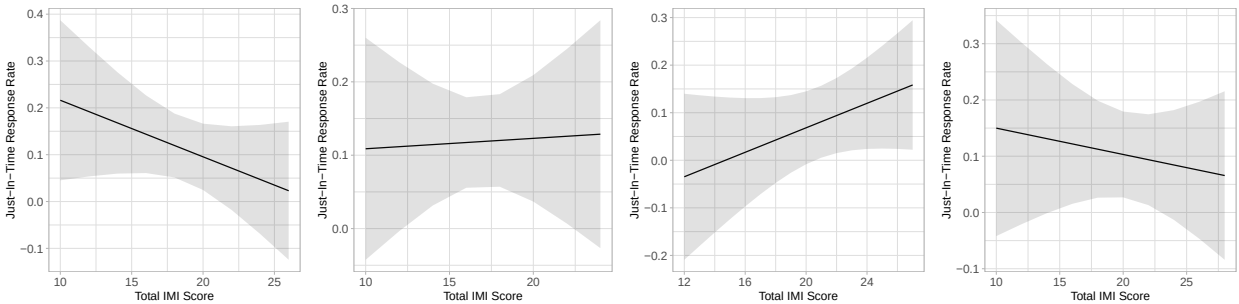
	Overall Response Rate	Just-in-time Response Rate	Conversation Rate	Average Response Delay (minutes)
(Intercept)	0.20	0.20	0.01*	−18.36
	(0.31)	(0.18)	(0.00)	(78.43)
total	0.01	−0.00	−0.00	5.17
	(0.01)	(0.01)	(0.00)	(3.88)
AIC	53.81	12.11	−343.63	293.11
BIC	61.38	19.67	−336.07	298.15
Log Likelihood	−22.90	−2.05	175.82	−142.56
Num. obs.	49	49	49	26
Num. groups: uid	20	20	20	16
Var: uid (Intercept)	0.09	0.01	0.00	864.26
Var: Residual	0.07	0.04	0.00	4980.16

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$



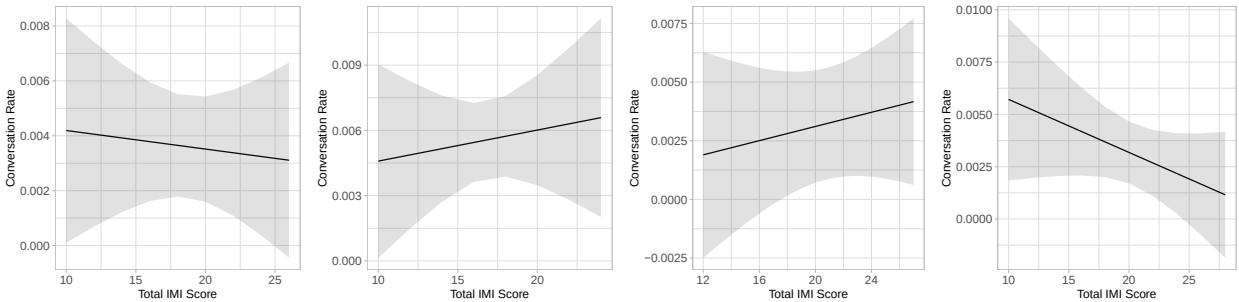
(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 62: Effect of total IMI scores on the response rate for intervention topics



(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 63: Effect of total IMI scores on the just-in-time response rate for intervention topics



(a) Mental Health (b) COVID-19 (c) Physical Activity (d) Diet & Nutrition

Figure 64: Effect of total IMI scores on the conversation rate for intervention topics

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