# Towards Design Guidelines for Effective Health-Related Data Videos: An Empirical Investigation of Affect, Personality, and Video Content

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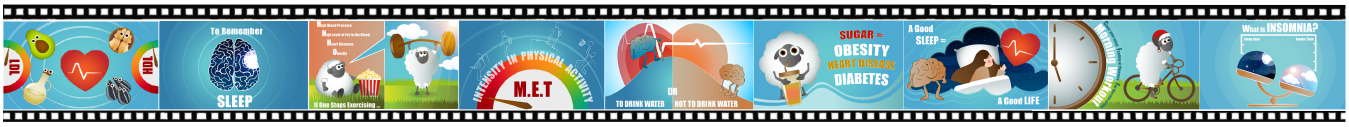


**Figure 1: Data Videos, or animated infographics, are short videos that present large amounts of data in an easy and engaging narrative format. For Study 1, we selected nine Data Videos focusing on three health-related topics: physical activity, sleep, and diet. This figure shows an example of the videos used in the study. The full list of videos and more detailed descriptions are listed in Appendices A & B.**

## ABSTRACT

Data Videos (DVs), or animated infographics that tell stories with data, are becoming increasingly popular. Despite their potential to induce attitude change [20], little is explored about how to produce effective DVs. Two studies explored factors linked to the potential of health DVs to improve viewers' behavioural change intentions. We investigated: 1) how viewers' *affect* is linked to their behavioural change intentions; 2) how these affect are linked to the viewers' *personality traits*; 3) which *attributes of DVs* are linked to their persuasive potential. Results from both studies indicated that viewers' negative affect lowered their behavioural change intentions. Individuals with higher Neuroticism exhibited higher negative affect and were harder to convince. Finally, Study 2 proved that providing any solutions to the health problem, presented in the DV, made the viewers perceive the videos as more actionable while lowering their negative affect, and importantly, induced higher behavioural change intentions.


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## CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Empirical studies in HCI**.

## KEYWORDS

Data Video, narrative visualization, data storytelling, persuasive technology, attitude change, personality, affect, actionable, solution, physical activity

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## 1 INTRODUCTION

Videos consisting of motion graphics with visual and auditory stimuli to tell a *story centered around empirical data*, called Data Videos (DVs) [5], are becoming an increasingly popular communication medium, often aimed at promoting behavioural change. For instance, a 2020 study examining YouTube videos covering COVID-19 vaccine development asserts that such videos are considered one of the major sources of information for many people [12]. While this popularity could be attributed to technology advancement (e.g., DVs can be viewed with smartphones and tablets anytime and anywhere), another reason could be attributed to DVs' ability to attract broad audiences on any given topic due to their narratives [37]. DVs can raise viewers' awareness about social issues, be

used for advertisement, and more recently for promoting healthy behaviours [20] for a wide range of viewers regardless of their data literacy background. Furthermore, DVs are short [5, 41], and obtaining information quickly is critical in today's fast-paced lifestyle. Additionally, DVs can present *actionable intelligence* components. A majority of COVID-19-related DVs, for example, focus on social distancing, mask-wearing, and vaccination, which are all actions that can be taken to reduce the spread of the disease. These videos usually show statistics and facts with a story that plays on viewers' affect, while drawing data-driven conclusions to encourage smart decisions. In short, DVs provide data-driven *actionable insights*.

Data visualization, or finding ways to best present the data at hand, is a major interest for HCI researchers. This interest is growing in parallel with the recent era of big data as enormous amounts of data are becoming available due to the technological advancements in sensors and embedded systems (e.g., smartphones). This naturally leads us to focus more on the visualization aspect in order to present the data in the most insightful and understandable way. Storytelling and narratives, as a natural means for human communication, have attracted the attention of visualization researchers and have proven to be very effective [37]. While visual data storytelling that depends on pictures and graphs (i.e., infographics), has proven efficacy in the field of data visualization, Gershon and Page argue that putting such visuals in a video format can take the story to a whole new level [37]. While "a picture is worth a thousand words", a video that elaborates and supports that picture with animation, audio narration, music, and sound effects is considered to be "worth a million pictures" according to Gershon and Page [37]. The potential of videos for data storytelling has been further amplified with the emerging popularity of data-based videos, or DVs, on social media platforms such as Youtube, Facebook, Instagram, and TikTok, which are easily accessible to a wide audience using various smart devices.

While DVs are beginning to attract the attention of HCI and visualization researchers to understand their building blocks [5] and provide tools to create such videos [7, 60], they are still a novel form of data visualization [5, 6, 20], and human perception in the context of DVs has not been explored fully yet despite its relevance. In this research, we explore DVs targeting common health issues (physical activity, sleep, and diet) to understand the factors affecting their ability to influence their viewers' health-related behavioural intentions. Given the brevity of DVs [5, 41], we focus on DVs' ability to influence their viewers' perception of the topic (i.e., targeting viewers' intentions/willingness to improve their behaviour, but not actual behavioural change). We chose to focus on generic behavioural health issues as opposed to specific health issues (e.g., diabetes or insomnia) for two reasons. First, due to the higher relevance of those general topics to the majority of the population, and hence relevance to our randomly recruited participants. Further, we believe that people with serious health issues are probably dealing with their issues with their own doctors (unique advice might be needed). While simple and well known to everyone, common health-related behavioural issues, such as poor eating habits and physical inactivity, could be linked to serious chronic consequences (e.g., cardiovascular diseases, obesity, and even some types of cancer) [1, 64]. People suffering from behaviour-induced health issues could benefit if they understood how their seemingly minor behaviours underlie their serious medical issues, or alternatively, the potentially beneficial outcomes if they changed those behaviours. We believe that the videos could serve as good reminders in the context of our study. DVs have a great potential to help in this area because of their compelling narrative nature. The storytelling aspect of DVs often arouses emotions in the viewers' minds. Research in advertisement and marketing demonstrates that the extent of such emotional experiences, or *affect*, plays a significant role in motivating viewers [45, 51, 56]. For example, one starts exercising after *feeling bad or at risk*. It is important to note that personality differences could underlie individuals' unique affective responses to a persuasive message. Indeed, individuals' responses to an affect-provoking persuasive message are unique [42, 46, 88]. Thus, investigation of viewers' personality traits could lead us to fruitful DV personalization strategies. Our exploration is crucial in identifying basic approaches to design DVs, as a data representation interface, from an HCI perspective to efficiently influence their viewers in a short amount of time. Understanding such personalization strategies has the potential to lead to new DV design tools that assist designers in making more effective and impactful DVs.

To explore the effect of DVs on viewers' perception, Study 1 focused on three questions: **RQ1:** how is viewers' affect, induced by DV viewing, linked to their willingness to alter their health-related behaviours?; **RQ2:** how are these affective responses linked to the viewers' personality traits?; and **RQ3:** what are the underlying attributes in DVs that contribute to their persuasive potential? Subsequently, to provide guidelines for video designers, Study 2 explored how we can tune participants' affect along with the narrative structure, with *useful information*, to improve the overall impact of DVs by altering the types of information.

## 2 LITERATURE REVIEW

First, we describe research investigating the effectiveness of Data Videos (DVs) as a narrative to communicate data, as this is the foundational media our work explores. We highlight some behavioural theories and studies in HCI and other related fields because we are interested in how DVs can promote positive behavioural changes. We then discuss work related to how affect is impacted by narrative structures, and how it could contribute to behavioural change intentions. As a factor influencing affect, we review studies about how personality traits impact responses to persuasive messages, by describing studies and strategies used in the literature of persuasive technologies. Finally, we briefly describe studies exploring measurements to assess the effectiveness and quality of health-related videos.

### 2.1 Data Videos as a Narrative

Data Videos (DVs) are motion graphics that incorporate factual, data-driven information to briefly tell informative and engaging stories with data [5–7], typically shorter than six minutes [41]. DVs are gaining popularity in various fields such as journalism [89, 90], education [41, 85], adverting and mass communication [78], as well as in political messages and campaigns [32, 79]. Due to their narrative nature, DVs are recognized as one of the seven forms of narrative visualizations [18, 77]. The power of DVs comes mainly from this narrative format; stories can convey information in an

engaging way that is more natural, seamless, and effective than text or even pictures [37, 43]. A well-told story can convey a large amount of information in a short period of time, in a way that viewers find interesting and easy to understand [37]. Moreover, they tend to be more believable and memorable [37, 48].

Narrative Transportation Theory states videos can transform and immerse the viewer in a totally different world [87]. The locations, characters, and emotion-laden scenarios then generate the opportunity to impact the viewers' own beliefs, emotions, and intentions [40, 60, 61]. Furthermore, a solid wealth of psychological theories support the persuasive power of narrative. The Extended Elaboration Likelihood Model argues that as people indulge in the narrative, with all its cues and stimuli, their cognitive processing of the narrative obstructs making counterarguments in response to the presented message [17, 81], making the message more persuasive even for those who are difficult to persuade otherwise [80]. Additionally, as per the Entertainment Overcoming Resistance Model, the entertaining aspect of a narrative also plays a role in reducing the cognitive resistance to the message presented, and hence facilitates persuasion [22, 59, 60].

Although DVs have great potential for motivating changes in behaviour, and have become an increasingly relied upon source for accessing information, it was not until recently that empirical investigations have focused on the component features and narrative characteristics that help to determine their capacity to persuade [5, 20]. Baber et al. [9] define narrative as a formal structure that constitutes a "sharable" story or report as opposed to the informal stories which could be "unstructured" and "ambiguous". The narrative is defined as a series of connected events that constitute a story [77]. The order in which these events are presented in a DV constitutes its narrative structure, and influences the understanding and the viewing experience of the video [23]. Amini et al. [5] examined 50 professionally created DVs to learn about their narrative structure. In their study, they divided the videos into temporal sections and coded them based on Cohn's [23] theory of visual narrative structure that broke the narrative into four categories: Establisher, Initial, Peak and Release. The Establisher is the entry point to the video which introduces its context, the Initial initiates the action, the Peak is where the most important events and the tension occurs, and the Release is where the conclusions are drawn [5, 23]. After analyzing and coding the videos based on these categories, the authors found that these categories are ordered differently based on video types: factual videos with multiple facts and information; comic and open-ended videos that do not have a conclusion or a takeaway message; and videos that exhibit multiple problems or those that provide multiple solutions to a single problem. The authors pinpointed some narrative structure patterns that are commonly used in DVs. By far, the most commonly used structure was the "well-balanced" pattern that strongly introduces and establishes the stories with facts till the peak is reached, then takes a descending direction towards the solutions or takeaway messages in the Release. The second most common pattern is one that ends at the peak leaving the viewers with an open question or unresolved problem.

Choe et al. [20] introduced a new class of Data Videos called Persuasive Data Videos or PDVs. This genre of DVs incorporates some persuasive elements inspired by and drawn from Oinas-Kukkonen and Harjumaa's [65] Persuasive System Design Model. Choe et al. [20] studied how incorporating some persuasive elements in a DV could improve persuasive potential of the video. Their PDVs had higher persuasive potential than regular DVs. Amini et al. [6] examined the effect of using pictographs and animation, two commonly used techniques in DVs. They found that the use of such techniques enhanced the viewers' understanding of data insights while boosting their engagement.

## 2.2 Affect and Data Video

In their investigation of pictographs and animation in DVs, Amini et al. [6] concluded that pictographs are effective because they trigger more emotions in their viewers, while the animation intensifies such emotions. This leads us to an important aspect of DVs: the viewers' emotional experience, or *affect*. Viewers' preference for multimedia, be it a performing art, internet video, or even music videos, is highly dependent on their arousal level and the intensity of their affect towards the media [10, 83]. Early studies assumed that TV viewers liked to watch shows that elicit positive emotions as opposed to negative emotions [38]. However, later research showed that while this might be true for real life events, it was not true for TV shows [62]. In a more recent study, Bardzell et al. [10] examined the intensity and valence of viewers' affect, as well as their ratings of internet videos. The results showed a correlation between the affect intensity and the liking of the video. As for the valence (i.e., positive or negative), the study showed that it is not the presence or absence of negative or positive affect that influenced the rating of the video. Rather it is the *emotional arc* that leaves the viewer emotionally resolved and hence liking the video, even if it started with negative emotions. This shows that negative emotions should be resolved in order to generate a satisfactory user experience with a narrative.

### 2.2.1 *The Role of Affect in Attitude and Behaviour Change.*

Affect plays an important role in the appeal as well as the persuasive power of media content [2, 15, 51]. According to theories in psychology, some of our attitudes have a cognitive base while others have an affective base [47, 69]. *Affective attitudes* emerge from our feelings towards certain topics or ideas. Some attitudes are influenced relatively easily through affect while others through logic and thoughts (i.e., cognition) [47, 69]. The Dual Process Model suggests two routes to persuasion: central and peripheral. The central route is the cognitive route in which the receiver of a message is willing and able to cognitively process the ideas [17, 69]. In contrast, the peripheral route processing is taken when the receiver lacks the motivation or ability to logically process cues in the message, and decides to agree with the message based on its emotional appeal (e.g., emotions triggered by the look or smell but not by the logic) [17, 51]. For instance, one might purchase a car based on its gas emission, cost, or functions (central route) or because of the way it looks (peripheral route). Thus, both cognition and affect are heavily involved in persuasion. Data Videos constitute a perfect persuasive medium that combines both the cognitive aspects (fulfilled by the data), and the emotional aspects (fulfilled via the narrative and the supporting audio and visual elements) needed for the persuasion process. While there has been some empirical

investigation of what types of data visualizations should be used in DVs [5], no clear guidelines have been provided regarding the effective emotional messaging strategies and techniques that ought to be used when developing DVs that aim at influencing the viewers' perception about health-related behaviours. In the field of marketing, an area focusing primarily on persuading and guiding the viewers to adopt a certain service or commodity, a wide array of studies have examined the kind of affect evoked by advertisements [45] and how they influence the viewers' attitudes [16]. However, no research has explored the function of affective changes induced by Data Videos as a potential persuasive medium.

#### 2.2.2 *Affect Valence and Persuasion.*

When it comes to health messaging aiming at attitude or behaviour change, the framing of the message often takes one of two strategies: a gain-framed strategy that focuses on the gains or positive consequences of following the healthy behaviour (i.e., positive emotions such as motivation or happiness); or a loss-framed strategy that focuses on the losses or the negative outcomes of failing to follow the healthy behaviour (i.e., negative emotions such as fear or worry) [34]. The Prospect Theory suggests that the same information can have different effects on their receivers based on how they are framed [34, 86]. The theory suggests that people would be more eager to avoid potential losses than they would be to attain potential gains. Rothman and Salovey [74] suggest the use of gain-framed strategy for persuasive messages targeting illness prevention behaviours such as physical activity, while a loss-framed strategy would be more effective for messages targeting illness detection behaviours like mammography [34]. The model of behaviour change, on the other hand, suggests that negative affect such as feeling worried or at risk is the first step towards attitude change [40]. In short, some research found significant effects of positive affect on behaviour change [68], some found undesirable effects of using negative affect [92], while others recommend using a threatening or fear-inducing approach for health issues such as smoke cessation [67] and physical activity [14]. While both approaches are worth exploring, in our studies we decided to focus on and explore the effects of using negative affect due to the nature of the existing high-quality videos chosen for the study based on the researchers' consensus.

#### 2.2.3 *Measuring Affect.*

There are two approaches to measuring affect: 1) the implicit approach, which relies on physiological recordings of individuals' biometric responses; and 2) the explicit approach, which relies on self-reporting of the users' affect during their exposure to the stimuli. While sensors and devices that can explicitly log biometric changes related to affect are very promising (e.g., heart rate, breath rate, respiration patterns, and galvanic skin responses (GSR)) [50, 83], they are often invasive, expensive, and the meaning of the data recorded can be ambiguous [50]. As for the explicit measurement methods, indicators such as final applause to a show, post-show surveys, interviews, as well as different scales are most commonly used. While less costly, such explicit approaches can capture somewhat skewed responses as the viewers' responses are normally affected by their peak emotion and the emotions experienced by the end of the show (i.e., the 'peak-end' effect) [26, 49, 50, 72]. Latulipe et al. [50] measured participants' GSR to a video in relation to their responses to two self-report scales. They found correlations between the explicit and implicit measures of emotions, showing that self-reporting of emotions can be reliable. Due to the online nature of our studies that was enforced by the pandemic, we adopted the *explicit* approach using scale items based on the Spielberger State Anxiety Scale [55].

## 2.3 Personalization in persuasive technology

Recent research indicates that the one size fits all model of persuasive technology is not so effective. Instead, researchers are showing the power of *personalized* persuasive systems which often explore the effect of personalities on persuasion [8, 19, 27, 44, 46, 47, 88, 91], making it essential for us to consider the personality aspect as a factor in our studies. The five-factor model (FFM) of personality offers five broad traits, referred to as the "Big Five", that capture differences in typical patterns of thought and behaviour that vary across individuals: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. The FFM is the most widely accepted model for personality assessment across diverse disciplines [29, 36, 47, 57, 76, 88] hence, we adopted it for our personality assessment. Halko and Kientz [42] explored the link between personality traits and people's perception regarding different persuasive strategies. They found correlations between participants' personality traits and persuasive strategies. For example, people who score high in Neuroticism tend to prefer negative reinforcement (i.e., removal of aversive stimuli), as opposed to positive reinforcement (i.e., rewards) to improve their behavioural patterns. They also found that neurotic people do not like cooperating with others to achieve their goals. Loss-framed strategies are commonly used in health DVs, so in our studies, we investigate the corresponding effects of this strategy on the viewers, given their personality differences.

## 2.4 Measures for assessing health-related videos

The content of a video, with its particular visual/auditory elements, animations, graphics, narration style, etc., contributes to the video's potential to affect attitude/behavioural change intentions. Various studies have examined ways to assess the quality of YouTube videos tackling health-related issues like exercise and low-fat diets [13, 31], bruxism [35], or general health videos [28, 33, 75]. For assessing the quality of YouTube Videos addressing health issues, Gabarron et al. [33] examined: 1) the usefulness and quality of the content; 2) Popularity-Driven Measures (i.e., number of views, shares, and video rating); 3) Heuristic-Driven Measures (e.g., length, narrative, visuals). However, quality assessment of such videos has been mainly done by experts (e.g., health professionals, major health organizations, IT researchers) [33] and very few studies have considered the feedback or judgements of the patients or viewers of such videos [24, 33].

In sum, research supports the potential of DVs to effectively convey health-related data through their affective influences. Studying affective responses in conjunction with personality traits is appealing because, understandably, affective responses are guided by individuals' traits. Exploration of personality traits and affective responses will show us ways to effectively personalize DVs for better communication. Additionally, to investigate common video

attributes from the viewers' perspective, in relation to potential attitude change, will be beneficial. While previous studies in other fields (e.g., psychology) explored related constructs [2, 15, 51]), our study focused on the users' perception in the frame of Data Videos in an applied manner so the designers of DVs can benefit from our research: Our explorations would contribute in providing general guidelines for DV designers who are interested in presenting health information.

# 3 STUDY 1: EXPLORATION OF AFFECT, PERSONALITY, AND POTENTIAL FOR ATTITUDE CHANGE

To understand the underlying mechanisms of health-related Data Videos (DVs) in relation to viewers' experienced affect, their personality traits, as well as the persuasive potential of DVs, Study 1 aimed to answer three main questions: 1) Does increasing viewers' negative affect levels lead to higher potential persuasion?; 2) Is there a relationship between participants' personality traits and their affective state after watching DVs?; and 3) What predicts higher potential attitude change in terms of personality traits as well as video content?

## 3.1 Study Administration

An online study was created using Qualtrics, and administered through Amazon Mechanical Turk (MTurk). To ensure higher data quality, we recruited MTurk workers who had completed a minimum of 1000 tasks prior to our study, with approval ratings higher than 95%. All participants received monetary compensation ($2.24 US) in compliance with the study ethics approval and MTurk payment terms. US and Canadian participants who were older than 18 were recruited.

## 3.2 Data Video Selection

We collected DVs focusing on three general health-related topics: physical activity, healthy sleep, and healthy diet. We systematically explored existing DVs with guidance taken from Amini et al.'s [5] study.

- First, two researchers collected over 100 videos using keywords such as 'healthy diet', 'dangers of not having enough sleep', 'importance of exercise', etc.
- We then removed videos containing erroneous information and/or did not follow Amini et al.'s [5] DV definition.
- Two researchers coded the remaining videos for *length*, *view count*, *source credibility*, and *information accuracy*.

The final list consisted of nine videos; three on each topic (see Appendix A).

## 3.3 Data Collection Instruments

**Personality Traits** We utilized a shortened, 10-item, version of the Big-Five Inventory [71] (e.g., "I see myself as someone who gets nervous easily", using a 5-point Likert scale) to assess participants' personality traits. This scale is widely accepted in personalized technology research [8, 66] in which personality assessment needs to be quick, and has been repeatedly validated. For instance, Gosling et al. [39] noted it has "reached an adequate level" in terms of predictive power and convergence with full scales in self, observer, and peer responses.[1]

**Table 1: General Persuasive Potential (GPP) items of the Persuasive Potential Questionnaire (PPQ)**

| **I feel that...** |
|---|
| the video would make its viewer change their behaviours. |
| the video has the potential to influence its viewer. |
| the video gives the viewer a new behavioural guideline. |

A Likert scale (1: Strongly Disagree to 7: Strongly Agree) is used.

**Affective State Self-Reports** Participants' negative affect were assessed using 3-items: "I feel anxious"; "I am relaxed (R)" [2]; and "I am worried", using an 8-point Likert scale based on the Spielberger State Anxiety Scale [55] where they eliminated a neutral choice. Out of the final nine videos we found suitable for the study due to their credibility, quality, and information accuracy, seven videos followed a loss-framed messaging strategy, and hence we focused on negative affect.

**Persuasive Potential Questionnaire (PPQ)** While DVs might have a great potential to influence their viewers, they are brief video clips. Hence, we suspect only one exposure to a video (as in our study) might not induce any effect at the behavioural level. Therefore, we focused on DVs' *potential* for persuasion at the perceptual level. To measure the potential of DVs, the Persuasive Potential Questionnaire (PPQ) [58] was adopted and adjusted to fit our context. We focused on the General Persuasive Potential (GPP) dimension of PPQ, see Table 1.

**Video Content Appraisal** Three questions examined participants' *appraisal of the video content* focusing on information characteristics: Novelty, Clarity, and Usefulness of the information in each DV (e.g., "The information provided by the video was useful to me", using a 7-point Likert scale, 1: Strongly Disagree to 7: Strongly Agree).

## 3.4 Study Progression

First, participants answered demographic questions, followed by the personality measure and the affect questions (i.e., baseline affective state). Participants then watched three DVs; one video from each topic, and answered questions after each. The videos were randomly selected from the sets of three videos per topic. The topic order was also randomized to avoid any priming and/or order effects. After watching each video (three videos in total), participants responded to:

(1) The three Affect-related items, for a post video measure;
(2) Video content appraisal questions;
(3) Questions for the General Persuasive Potential (GPP) of the video (see Table 1);
(4) Finally, participants reported any health issues that would prevent them from following the video's advice.

After completing these four steps for each video, participants engaged in a 12-piece jigsaw puzzle game, which was designed to

[1] According to Google Scholar search, this scale has been cited in 3468 articles at the moment of writing; August, 2021
[2] (R): item is reverse scored

take at least one minute. This step was added based on various psychology studies in which a filler task (e.g., a visuospatial task like a word puzzle, counting numbers from 7 to 0) is used between tasks [11, 54, 82] to help participants neutralize their affective state by focusing on an unrelated task [70, 82]. After the filler task, participants repeated the four steps for the next video.

## 3.5 Results

On average, participants took 26 minutes to complete the study. Data-fitting assumptions for each analysis were checked and non-parametric options were used with report of medians instead of means, whenever appropriate. Due to our smaller sample size, more detailed results including null effects along with effect sizes (which is independent from sample size issues [84]) are reported in Appendix F so the readers can examine the potential Type II error.

### 3.5.1 Participants.

One hundred and two people with ages ranging between 21 and 70 participated in our study ($M$ = 37.29, $SD$ = 12.01): 68 identified as male, 33 as female, and one preferred not to report; 60% of them self-identified as white, 20% did not report their ethnicity, and the rest self-reported as Hispanic, Black, Asian, or American. Almost all of the participants (98%) reported their first language was English, and 83.3% of them reported they had at least a Bachelor's Degree.

### 3.5.2 Data Quality Control.

To filter out potentially unreliable responses, a verifiable (i.e., Gotcha) question was designed to be readily solvable as long as the participants read the question ("How many words do you see in this sentence?"): 78 cases remained for the analyses[3]. When appropriate, we further filtered out responses based on their answer to a question ("I have health issues that prevent me from following the advice provided in the video") in each of the three topics. This was designed to ease potential confounds as much as possible (i.e., participants' lack of willingness to change their behaviour might not be reflecting their reactions to the DVs. Instead, this could be due to their health issues)[4].

### 3.5.3 Data Preparation.

First, we explored inter-item reliability for each scale (e.g., GPP, affective response, etc.), and when Cronbach's Alphas were higher than our standard ($\alpha \geq .70$) based on Nunnally and Bernstein [63], we computed the mean across all items to be used as an index:

- *Negative Affect Index:* Cronbach's Alphas were higher than our standard ( $.73 \leq \alpha \leq .82$) for participants' negative affective responses per topic (Physical Activity, Sleep, and Diet), indicating that items for each scale had sufficient internal consistency. [5] Thus, the mean of three items was computed for each topic. Then the correlations between these means for each topic were also investigated. They were all significantly and highly correlated (.810 <*rhos* <.830, *ps* <.001) [4]), implying that if a participant's affective response was negative from viewing one video, it was likely that they experienced negative affects from viewing other videos as well (i.e., implied underlying *personal tendency*). Thus, the mean across all the topics was used as an index for Negative Affect.[6]
- *GPP Index:* The index for GPP was also created in the same manner. Cronbach's alphas ranged between .81 and .91 per topic. Further, GPP for one topic was correlated with the GPP for other topics (.555 <*rhos* <.719, *ps* <.001)[7], and the mean of scores across all the topics was generated, and used as a GPP index.[8]

### 3.5.4 Data Analysis and Findings.

**Negative Affect and GPP:** We explored whether overall GPP could be predicted by negative affect. Negative affect predicted GPP, $F$ (1, 76) = 4.056, $p$ =.048, $R^2_{adj}$ = .038, $\beta$ = -.225. Interestingly, *participants' increased levels of negative affect predicted lower GPP*, (i.e., it was harder to motivate the viewers to alter their health-related behaviour when they had high levels of negative affect after viewing the video).

**Predictors of GPP:** We conducted a multiple regression analysis, using a stepwise method, to explore how content appraisal variables (i.e., Information Novelty, Clarity, and Usefulness), and personality traits could predict GPP altogether. Content appraisal and personality traits are unique as content belongs to the DV design while personality traits belong to individual viewer. Thus, they are conceptually independent routes to influence the viewers' perception (design itself & target selection). Only two predictors remained in the model, which explained approximately 66% of the variability in GPP (1; Information Usefulness, $\beta$ = .718, $p$ <.001 , 2; Neuroticism, $\beta$ = -.143, $p$ =.036), $F$ (2, 75) = 74.87, $p$ <.001, $R^2_{adj}$ = .657 (see Fig 11 in Appendix F for details on the excluded variables). When viewers perceive the information in DVs as useful, it was particularly easier to influence the viewers' attitude. However, DVs will be less effective at convincing individuals who have highly neurotic tendency to change health-related behaviours. For those who score high on neuroticism, a differently framed narrative may be more effective. Our model confirms that consideration of both routes (i.e., video design & target selection) are useful in achieving higher persuasive potential.

**Personality Traits and Negative Affect:** To examine the relationship between personality traits and the levels of negative affect, correlations between each personality trait and negative affect were explored (see Fig 12 in Appendix F). Negative affect was positively correlated with neuroticism, *rho* (78) = .594, $p < .001$, but negatively correlated with conscientiousness, *rho* (78) = -.363, $p$ = .001; no other traits were correlated with negative affect (b in Figure 2). Highly neurotic people experience higher levels of negative affect by DV viewing, unlike conscientious people who are less sensitive.

**Data Videos and Negative Affect:** Next, we turned to examine the characteristics of DVs. As seen in Figure 3, each DV induced different levels of negative affect. DVs that induced the highest (Diet 1) and the lowest (PA 1) negative affect were examined closely.

[3] 23.5% of our participants failed to pass our Gotcha question.

[4] Four participants responded "Yes" after viewing a physical activity themed video, four others responded "Yes" after watching a sleep themed video, and finally, three others responded "Yes" after watching a diet themed video. A pairwise deletion method was applied to this selection throughout the analyses.

[5] One item ("I am relaxed") was reverse coded for the index computation.

[6] Negative Affect refers to the Negative Affect Index wherever mentioned.

[7] This implied another underlying *personal tendency*; if a participant perceived high levels of general persuasiveness in one video, they perceived higher levels of general persuasiveness in other videos as well

[8] Mentions of GPP in the analysis refer to the overall GPP Index.

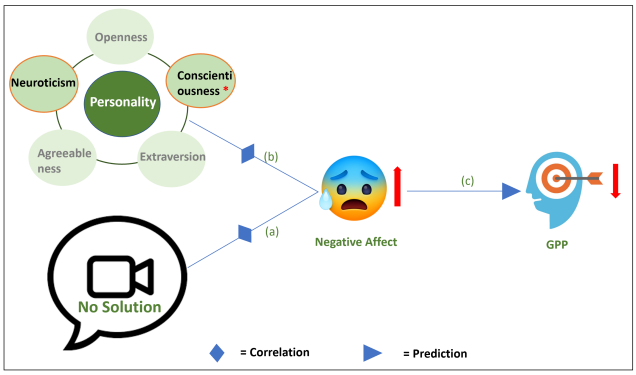


**Figure 2: Negative Affect was correlated with the Video Content (a) and Personality Traits of Neuroticism and Conscientiousness (b). Finally, Negative Affect predicted viewers' unwillingness to alter their behaviours (c).**
***: negative correlation**

Wilcoxon Signed Ranks Tests revealed that viewers' negative affective responses were increased after watching Diet 1 Video (Pre-video *Mdn* = 3.00; Post-video *Mdn* = 5.00, $p = .001$), but not after the PA1 Video (Pre-video *Mdn* = 2.00; Post-video *Mdn* = 1.67, $p = .48$). To understand this differential effect, two researchers coded the videos' contents qualitatively and found that Diet 1 Video included a fear inducing message without any clear solution. Consequently, participants' negative affect remained high even after the video. We further observed that none of the three DVs that induced the highest levels of negative affect (see Fig 3) contained concrete solutions (see Appendix B). Thus, it appeared that not providing solutions was linked to heightened negative affect.

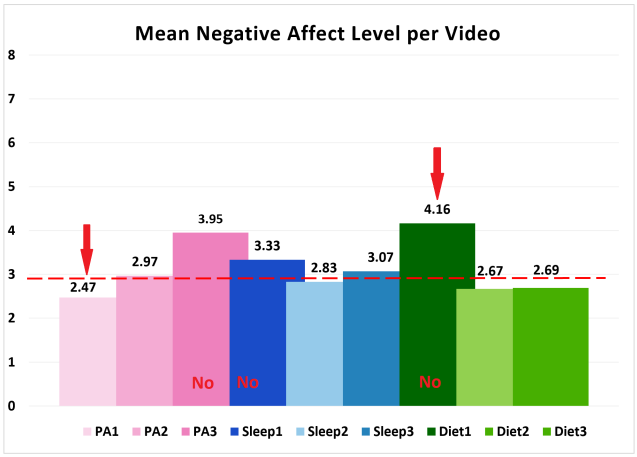


**Figure 3: Negative Affect by video. (Note PA = Physical Activity). The horizontal dotted line indicates the mean across all 9 videos ($M = 2.96$). Videos that induced the highest negative affect (Diet 1, PA 3 & Sleep 1) did not have solutions.**

### 3.6 Discussion

Due to the nature of common health Data Videos which regularly contain fear-inducing messages, this study explored negative affect (i.e., anxiety, worries, and not being relaxed) in response to those messages specifically about physical activity, sleep, and diet. We observed that DVs without clear solutions to their fear-inducing messages kept viewers' negative affect higher. We also found that heightened levels of negative affect predicted a lower viewer willingness to change their behaviour. Moreover, the levels of negative affect viewers experienced were linked to their own personality traits: individuals who scored high on neuroticism experienced higher levels of negative affect while those who scored high on conscientiousness were less likely to experience highly negative affect. These findings flag the potential risk of including heavily loss-framed messages (i.e., messages that focus on negative outcomes of not following a certain behaviour) in DVs especially for highly neurotic individuals who have higher tendency to experience negative affect while being harder to persuade. While loss-framed messages are commonly included in DVs, and their effect is validated in psychological research, such messages could potentially backfire in DVs: the messages could be perceived as less convincing when a suitable or useful solution is not presented. Finally, perceived information usefulness played an important role in predicting GPP. However, information usefulness is a broad construct: understanding what constitutes information usefulness might be essential in producing powerful DVs. We acknowledge that our sample size became smaller than we originally planned, after removing invalid data points, and another study with a larger sample size will be fruitful especially in examining our null effects (see Appendix F). We made several important discoveries (e.g., how information usefulness is related to GPP, how negative affect influences GPP within DVs) even with the smaller sample size, however. Thus, Study 2 further explores how we can structurally resolve negative affect with useful information.

## 4 STUDY 2: EXPLORATION OF THE EFFECT OF PROVIDING SOLUTIONS TO HEALTH-RELATED DVS ON THE LEVELS OF NEGATIVE AFFECT AND PERCEIVED USEFULNESS.

To follow up on our findings in Study 1 regarding perceived information usefulness, we developed a nomological network to break down the construct (see Appendix C). The overall goal of Study 2 was to explore the means to effectively resolve the negative affect along the narrative arc with *useful* information. Our literature review revealed that an actionable solution is a part of perceived information usefulness (Appendix C). Interestingly, since a lack of solution was linked to viewers' negative affect in Study 1, we decided to explore the role of solutions in DVs. Specifically, we investigated the effect of providing two types of solutions: 1) a broad/generalizable solution, and 2) a concrete/actionable solution, compared to having no solution at all (baseline). We hypothesized that, by providing concrete solutions, the viewers' anxiety levels could be assuaged as they feel the issues are resolvable. This hypothesis is based on results from Study 1 and Cohn's [23] narrative

structure that starts with introducing the problem (*Establisher*), followed by a rise in action (*Initial*) where the events intensify, or the negative consequences of not following a healthy behaviour (in the case of DVs targeting health issues) are listed, till the *Peak* is reached. Finally, the narrative takes a descending direction towards a resolution to the problem (*Release*). This *'well-balanced'* narrative structure is very common in DVs [5] and is consistent with Bardzell et al.'s [10] findings regarding viewers' liking of general internet videos. They found that viewers liked videos that succeeded to utilize an *emotional arc* that managed to resolve the issues discussed by the end of the video, even if the video started with negative emotions [10]. Hence, we anticipated that presenting the issue will increase the level of anxiety, but this will be soon alleviated if solutions are presented. This reduction in anxiety level might be a key to improving the persuasive potential of the videos. We also believe that the effect of providing a solution is twofold: it should reduce viewers' negative affect, and should improve the perceived usefulness of the video which then aids in the persuasive potential.

## 4.1 Study Administration

We chose physical exercise as a topic because since the COVID-19 pandemic started, many people lost their access to the gym or were prevented from participating in any training or group physical activities (i.e., reduced physical activity level). Parallel to Study 1, Qualtrics survey was administered through MTurk with the same workers' requirement criteria with monetary compensation ($2.47 US). Again, participants were from the US and Canada. The study was a between-subjects design with three conditions: Control/No Solution, Generalizable Solution, and Concrete Solution. Participants completed survey questions before, after, and between segments of a DV on physical activity.

## 4.2 Data Video Development

We used a DV developed by the World Health Organization, titled 'Move for Health', as the basis for our stimuli [30]. The original video starts by stating that modern life has made us less physically active (*Establisher* in the narrative arc (see the yellow arc in Fig 4). The video lists the dangers of physical inactivity in the *Initial* phase (e.g., fourth leading risk factor for mortality worldwide, a major cause of severe diseases such as diabetes, etc.), the video then reaches its *Peak* by referring to office workers who remain seated for eight hours a day and how that could lead to severe health issues. Thereafter, the video takes a descending direction by giving some advice and suggestions (i.e., solutions) in the *Release*. They advise the viewers to stand up and stretch while in the office, then further encourage them to work out and be physically active by stating that physical activity is simple and can be done anytime and anywhere. The video uses walking as an example of simple but important physical activity that is free and easy to practice. The video concludes by providing concrete advice to practice 30 min of moderate-intensity physical activity 5 days per week, accompanied by images of a variety of suggested activities (e.g., basketball, hiking, etc.). We adjusted and used this video as follows:

(1) **Condition 1** *'Data Video with no solution' (baseline):* The video ends immediately after the peak, before any suggestions or solutions are provided (refer to video 1 in the supplementary material).
(2) **Condition 2** '*Data Video with broad/generalizable solutions':* This video provides a very general suggestion/solution after the peak, saying "physical activity is simple and can be done anywhere and anytime" (refer to video 2 in the supplementary material).
(3) **Condition 3** *'Data video with actionable/concrete solutions':* This video provides specific actionable solutions in addition to the general advice provided in video 2. Two concrete solution ideas were provided: walking (from the original video) and brisk walking (content and animation developed and added to the original video). To make the added advice useful and actionable, the video explains exactly what brisk walking is (e.g., "Brisk walking = 100 steps per minute or 17 steps per 10 seconds. Just walk fast enough so you can talk but not sing" (refer to video 3 in the supplementary material). Facts about brisk walking are taken from [73][9].

The film frames at the bottom of Figure 4 show a brief summary of the three videos.

## 4.3 Data Collection Instruments

Study 2 followed the same scales as Study 1 for measuring *personality traits* (Rammstedt and John's [71] 10-item Big-Five Inventory) and *Persuasive potential* (Meschtscherjakov et al.'s [58] PPQ). Additionally, we measured:

**Health Perception:** We measured participants' perception of their own physical activity using the statement "Generally speaking, I am being physically active" with a 7-point Likert scale: 1 indicating Strongly Disagree to 7, Strongly Agree.

**Affective state:** We adjusted the three questions in Study 1 to be focused on physical activity (see Table 2).

**Actionability scale:** Seven questions assessed the video content in terms of its utility or actionability (e.g., "Generally, the video provided concrete steps to address the problem." on a 7-point Likert scale: 1 indicating Strongly Disagree to 7, Strongly Agree). These questions were created based on the *'Reduction'* and *'Tunneling'* principles from the Primary Task Support and *'Suggestions'* from the Dialogue Support categories in Oinas-Kukkonen and Harjumaa's [65] model for persuasive systems (see Appendix E for the actionability scale question items).

## 4.4 Overall Study Progression

First, participants answered demographic questions followed by the 10-item personality questions. Participants also answered a question regarding their physical activity level ("Generally speaking I am physically active", on a 7-point Likert scale: 1 indicating Strongly Disagree to 7, Strongly Agree). Thereafter, participants started the video viewing section (see Appendix D). To capture the changes in participants' affective reactions to the two solution videos, their

[9]To avoid any confounds, three HCI researchers ensured that the added content followed the same theme and animation style as the original video and also ensured smooth transitions between different scenes.

anxiety levels were assessed using the affective state questions (see Table 2) three times: 1) prior to the video viewing, 2) at the *Peak* point, and 3) after *Release* (i.e., Post video). For the control video, however, it was assessed twice: 1) prior to the video viewing (i.e., Pre-Video), 2) at the *Peak* point, because the video ended at its Peak point. Check Appendix D for a visual representation of the video viewing experience. After completing the video viewing, participants responded to:

**Actionability Questions:** measure perceived *utility or actionability* of the video (see Appendix E).
**Video Content appraisal:** assess perceived novelty, clarity, and usefulness of the DV content.
**Health barriers:** assesses whether it is possible for participants to follow the advice provided in the DV.

## 4.5 Results

The average completion time for Study 2 was roughly 15 minutes. Data fitting assumptions for each analysis were checked and non-parametric options were used when appropriate. Thus, medians (instead of means) are reported when applicable. Due to multiple comparisons, we used the Holm-Bonferroni method[10]. More detailed results, including null effects along with effect sizes, are reported in Appendix F.

### 4.5.1 *Participants.*

We recruited 119 participants [11] who varied in terms of gender, age, and education (see Table 3).

### 4.5.2 *Data Quality Control.*

The verifiable question used in Study 1 was asked again to filter out potentially unreliable responses. Applying a listwise deletion method for cases with wrong responses to the verifiable question left us with 109 valid cases out of 119; 8.4% of our data was considered invalid. We further filtered out responses when participants answered "yes" to the question *"I have health issues that prevent me from following the advice provided in the video"*. Eighty-two valid cases remained for our analyses (n = 82).

### 4.5.3 *Data Preparation.*

For each scale, we first checked inter-item reliability scores within the scale items (negatively coded items were reverse coded first) by investigating Cronbach's *alpha*s: 1) GPP ($\alpha$ = .84); 2) Negative Affects ($\alpha$ = .95); and 3) Actionability items ($\alpha$ = .89). Since all scales encapsulate items that are sufficiently correlated (i.e., $\alpha \geq .70$ [63]), we created an aggregate index for each [12]. Similarly, we created an index for each personality domain by aggregating its two items.

*Negative Affect measures:* In the study we measured participants' negative affect two or three times depending on the condition (circular points on the line chart in Figure 4 represent times when negative affect was measured). Each time, we measured negative affect using the 3 anxiety questions in Table2. After checking for inter-item reliability between the anxiety scale items, we created 3 indices:

(1) **pre anxiety:** aggregate of participants' anxiety level *before* watching any of the three video conditions.
(2) **peak anxiety**: the aggregate of participants' anxiety level *after watching the first segment of the video*, before solutions are presented (i.e., at the Peak).
(3) **post anxiety**: the aggregate of participants' anxiety level *after watching the second segment of the video* in which the solutions are presented (i.e., after the release in case of the solution video conditions).[13]

As the line graph in Figure 4 shows, participants in all three conditions exhibited elevated negative affect after viewing the first segment of the video which presented negative outcomes of not having enough physical activities. Note the change in anxiety levels cannot be attributed to the video condition yet because the videos were identical across all three conditions at this stage of the viewing (segment (a) in Figure 4). After exposing participants in the experimental conditions (i.e., the generalizable and actionable solution conditions) to the second segment of the video, in which the solutions are provided, their anxiety levels started to decline (post: Condition 2; *Mdn* = 2.67, Condition 3; *Mdn* = 5.33). As for participants in the control condition (i.e., the video with no solution), their anxiety level remained elevated as the video ended at its peak(*Mdn* = 4.33). For the analysis, we only considered the **Anxiety decrease/drop** per condition, which is the difference between median anxiety levels at the end of the video (post anxiety) and at the peak (peak anxiety) (see the red circles in Figure 4). This is the only measure that can be attributed to the condition effect.

### 4.5.4 *Data Analysis and Findings.*

**Perceived Actionability:** We checked if our video manipulation (i.e., adding two different types of solutions in the video) succeeded in making the videos more actionable. As Figure 5 shows, the trends are as anticipated. Next, a Kruskal-Wallis test examined if there is a significant difference between the three conditions in terms of actionability. We found a significant condition effect ($p$ = .004). Pairwise comparisons using Mann-Whitney U tests (details available in Appendix F) further found that participants in the experimental conditions perceived the videos as more actionable compared to participants in the control condition. Interestingly, there is no significant difference between the two experimental conditions (i.e., both of the experimental videos are significantly more actionable than the control video but are not different from each other)[14]. This indicates that, to improve perceived actionability, video designers can simply add a general solution to the video instead of detailed solutions. This is an interesting finding as adding concrete solutions usually requires more resources (e.g., detailed information search, more design effort, and more time added to the video).
**Actionability and Usefulness:** We examined whether actionability leads to information usefulness. As our nomological network suggested (see Appendix C), actionability accounted for the variation in usefulness, $F$ (1, 81) = 63.03, $p$ < .001, $\beta$ = .664, $R^2_{adj}$ = .434.

[10]The Holm-Bonferroni method was applied to balance both Type 1 and 2 errors. As the alternative to Bonferroni's correction, where a consistent threshold is applied, Holm-Bonferroni's method progressively adapts the threshold in which hypotheses are rejected based on the ranks of the mean scores of the comparisons.
[11]Those people who participated in Study 1 were not recruited for Study 2.
[12]Whenever any of these four aspects is mentioned, they refer to the corresponding index.
[13]For the video with no solution, post anxiety will be the same as peak anxiety as there is no second segment, so participants' anxiety levels remain the same.
[14]Note, however, our sample size was smaller: for a better understanding of these null effects, please see Appendix F

**Table 2: Physical Activity Negative Affect Question Items**

| Please read each statement carefully, and select the appropriate answer that best describes how you feel **right now.** |
|---|
| I feel **worried** about my health due to my low physical activity level. |
| I feel **nervous** about my physical activity level. |
| I feel **anxious** about my physical activity level. |

*A Likert scale (1: Not at all to 8: Extremely) is used.*

**Table 3: Participants' Demographic Information**

| **Total Participants= 119** | |
|---|---|
| Gender | Male (66%), Female (30%), Other (4%) |
| Age | 18-34 (39%), 25-49 (40%), 50-64 (18%), over 65 (3%) |
| Education | High school or equivalent (17%), Bachelor's degree (61%), Graduate degree (19%), Other (3%) |
| Gotcha Question | Correct (109 participants) , Wrong (10 participants) |
| Health Issues | No (82), Yes (27) |

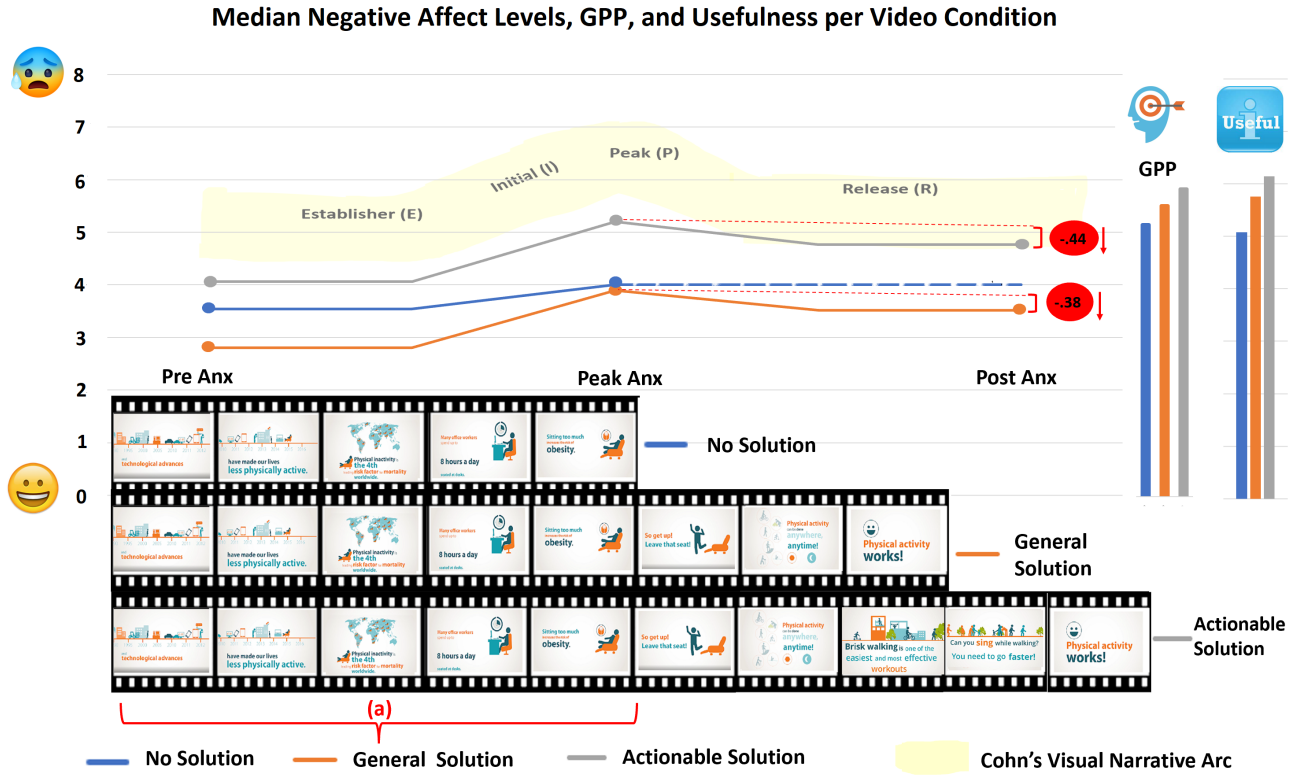


**Figure 4: The yellow curve in the background is a rough representation of the common narrative arc and does not follow any scale. The line charts represent the fluctuation in participants' negative affect during the video viewing. Each line represents one video condition. The film frames at the bottom summarize the 3 video conditions and show where they end relative to each other and to the narrative arc as well as the affect fluctuation trends. (a) is identical across all three conditions, and it represents the first part of the videos in which the negative outcomes of not having enough physical activity are listed (E + I + P). The bar charts (right side) represent median GPP and median usefulness by video condition.**

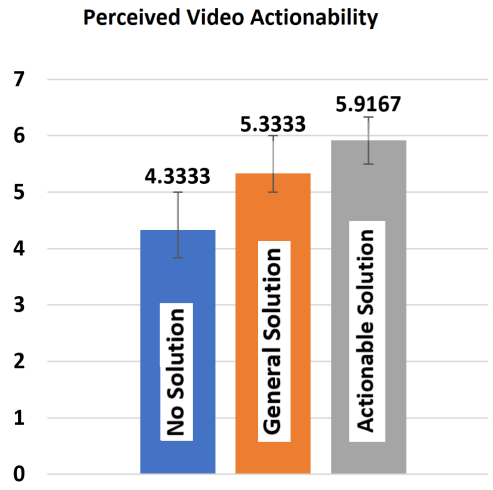


**Figure 5: Medians of Perceived actionability per video condition. Error bars represent 95% CI.**

Higher actionability predicted an increase in the usefulness of the information ('a' in Figure 6).

**Usefulness:** We also investigated the link between the video condition and perceived information usefulness. We entered the video condition as a predictor of information usefulness in a linear regression. The video condition predicted information usefulness ($F$ (1, 81) = 6.602, $p$ = .012, $\beta$ = .276, $R^2_{adj}$ = .065). The more actionable and detailed solutions provided in the video, the more useful it was considered. Further, a Kruskal-Wallis Test found that there was a significant difference in information usefulness among the three conditions ($p$= 0.028). Subsequent Mann-Whitney U Tests (details including effect sizes are available in Appendix F) found that, compared to the control video, the video with actionable solutions was perceived as significantly more useful ($p$= 0.011). No other significant effects were found. To improve perceived usefulness of information, thus, adding actionable solutions is essential (i.e., general solutions are insufficient).

**Usefulness and GPP:** Finally, we tested whether perceived information usefulness predicts general persuasive potential or GPP as found in Study 1. We entered usefulness as a predictor of GPP in a simple linear regression, and information usefulness did predict GPP ($F$ (1, 81) = 122.97, $p$ < .001, $\beta$ = .778, $R^2_{adj}$ = .601). Consistent with our findings in Study 1, information usefulness was a very strong predictor of GPP; it explained 60% of the variability in GPP ('b' in Figure 6).

**Actionability, Anxiety, and GPP:** To explore the effect of having solutions on easing participants' levels of negative affect, we conducted a linear regression with the video condition as a predictor of the level of drop in anxiety. The video condition predicted the drop in anxiety levels ($F$ (1, 81) = 63.03, $p$ = .030, $\beta$ = .240, $R^2_{adj}$ = .046). When the video provided a solution, the anxiety levels declined further, meaning that participants experienced more relief at the conclusion of the video. When no solution was provided,

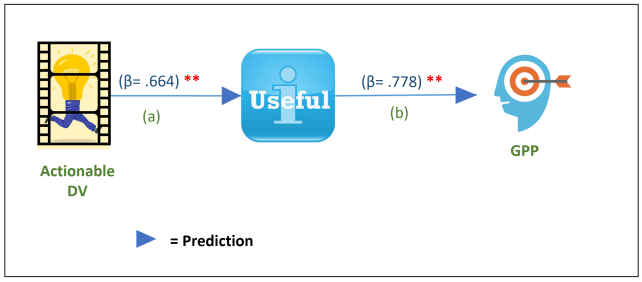


**Figure 6: Videos with solution are more actionable, actionable DVs predicted usefulness with $\beta$ = .664. Usefulness predicted GPP with $\beta$ = .778.**
**: $p$ < .001.**

unlike the two solution conditions, participants' negative affect remained elevated at the end of the video. A pairwise comparison using the Mann-Whitney U test showed that there was no significant difference in the drop in anxiety levels between the two experimental conditions (generalizable and actionable solutions), please see Appendix F for more details. This finding informs us that incorporating *any* kind of solution in DVs can ease the anxiety that viewers develop from their exposure to the video. Next, we entered anxiety drop as a predictor of GPP in a linear regression model. Anxiety drop predicted GPP at marginal level[15] ($F$ (1, 81) = 3.022, $p$ = .086, $\beta$ = .191, $R^2$ = .036).

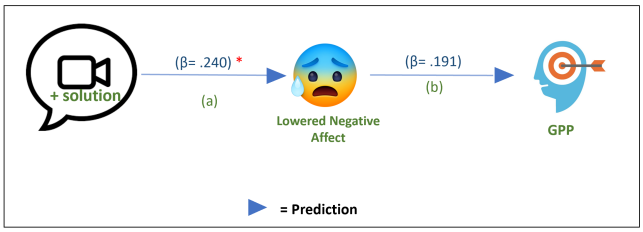


**Figure 7: The video condition predicted a drop in negative affect (a); Video with detailed solutions induced the highest decrease in negative affect while video without solution did not decrease participants' negative affect. The drop in negative affect predicted GPP (b), marginally.**
*: ***P* < .05.**

**Solution and GPP:** Lastly, we examined the effect of having a solution (generalizable solution or actionable solution) vs. no solution on overall GPP. For this analysis we split our data into only two conditions: 1) DV with no solution, 2) DV with solution (this included the general and actionable solution data). We entered the solution condition as a predictor of overall GPP in a linear regression model. Adding a solution did predict GPP ($\beta$= .242, $p$=.028. $R^2_{adj}$= .047). Videos with solutions (general or actionable) were seen as more persuasive than the video without a solution.

[15]We believe this marginal effect could have been due to a smaller N since we did find a small effect in this analysis. Note $R^2$ = .036 is considered to be a small effect according to Cohen [21]

**Personal Aspects Influencing Negative Affect:** To understand the dynamics underlying participants' personal tendencies to feel anxious or worried, we examined two factors:

**Personality Traits and Negative Affect:** With multiple linear regressions using a stepwise method, we explored personality traits as predictors of overall negative affect index (mean of pre, peak, and post anxiety). We were able to replicate the findings from Study 1: only Conscientiousness ($\beta$ = -.388, $p$ <.001 ) and Neuroticism ($\beta$ = .358, $p$ = .001 ) predicted overall negative affect $F$ (2, 80) = 68.64, $p$ < .001, $R^2_{adj}$ = .401.

**Health Perception and Negative Affect:** We also looked at the relationship between participants' perceived physical activity levels and the anxiety levels they reported after watching the "threatening" part of the video (i.e., peak anxiety). A linear regression analysis found that participants' health perception predicted negative affect with a negative *beta* ($\beta$ = -.316, $p$ = .004, $R^2_{adj}$ = .088). When participants perceived themselves as less physically active they felt more anxious and worried after watching the video.

These findings tell us that highly neurotic people are more susceptible to fear-inducing messages while people who score high in conscientiousness are more resilient to such messages. Also, when participants perceived themselves as less physically active (i.e., presumably the targets of such DVs), they tend to become more anxious when presented with threatening (or loss-framed) messages related to physical inactivity. Thus, designing different versions of DVs based on the viewers' personality traits, specifically on neuroticism and conscientiousness, may motivate viewers more efficiently.

# 5 DISCUSSION

To get a better understanding of the persuasive potential of Data Videos targeting common health issues, this research focused on the exploration of viewers' affect, personality, the type of provided information, and the structure of Data Videos. The first study asked three questions; how is viewers' affect linked to their willingness to alter their health-related behaviours?; how are these affective responses linked to the viewers' personality traits?; and what are the underlying attributes in DVs that contribute to their persuasive potential? With the findings of Study 1, Study 2 then focused on providing guidelines for video designers by exploring how we can adjust participants' affect along with the narrative structure to improve the overall impact of DVs by altering the *types of information* provided. In this section, we first discuss how our findings are related to and explained by, previous work. We also present a set of initial guidelines which designers of DVs can follow.

We observed that DVs lacking clear solutions to their loss-framed messages kept viewers' negative affect higher after their video viewing. Then, these heightened levels of negative affect predicted a lower viewer willingness to change their behaviour. Moreover, the viewers' levels of negative affect were linked to their own personality traits. While our results cannot tell us *how exactly* we should design trait-specific DVs, they flag the potential risk of including heavily loss-framed messages. While loss-framed messages are very commonly included in DVs, and the relationship between fear and persuasion has been validated in numerous research [25, 53], in the context of DVs, such fear/anxiety-inducing messages could potentially backfire; The message could be perceived as less convincing if viewers' negative affect were left unresolved by the end of the video. Interestingly, our results are consistent with earlier psychological investigations of smoking. For example, one study revealed that fear was effective in *motivating* behaviour change, but only when the message informed individuals how to succeed in smoking cessation efforts; loss-framed message with solutions[52].

This research provides design guidelines (GLs) to improve the persuasive potential of DVs targeting health issues in two directions: 1) the content and narrative structure of the videos; and 2) personality-tailored guidelines.

## 5.1 Data Video Content: Related to RQ1 & 3

To increase the persuasive potential of health-related DVs that normally follow a loss-framed messaging style (i.e., messages that show the consequences of failing to take certain actions), designers should make sure to follow a *'well-balanced'* narrative structure: Presenting the problem and all the threats associated with it, should be followed by solution(s) or suggestions(s) to balance the level of negative affect viewers experience throughout the video viewing, and to leave the viewers emotionally resolved by the end of the DV (Study 1). Our studies proved that including solutions in health-related DVs makes the viewers perceive the videos as more actionable and useful, eases viewers' anxiety levels, and makes the videos more persuasive. Importantly, we observed trends around solution type: while presenting simple general solutions was effective in reducing anxiety levels and improving the actionability of DVs, detailed actionable solutions that provide very specific advice consistently yielded the best outcomes (Study 2).

***GL1:*** *DVs targeting health issues should include a solution to the presented problem. This should leave the viewers emotionally resolved by nicely balancing the levels of negative affect they experienced throughout the video viewing.*

***GL2:*** *Adding detailed and specific solutions to DVs is clearly an effective way to make them useful and less stressful. However, if the video length is an issue, while not ideal, adding a simple solution would also improve the power of DVs.*

## 5.2 Personalization of DVs: Related to RQ1 &2

As for our contributions in terms of personalization of DVs, our findings confirm that when watching DVs which target a health issue, people react differently to affect-provoking messages due to their underlying personality traits. Highly neurotic individuals experience higher levels of negative affect when exposed to threatening messages, while highly conscientious individuals have a higher tolerance for receiving such messages. Neurotic people are also less likely to be persuaded via watching DVs. Furthermore, people who perceive themselves as more vulnerable to the health issue discussed in the video (i.e., possibly the target of DVs) are more sensitive to the threatening messages.

***GL3:*** *Designers should be extra cautious when targeting individuals with neurotic tendencies in terms of the amount and/or levels of threat contained in their messages or else their DVs may backfire.*

***GL4:*** *If designers are targeting individuals who feel vulnerable to the health issue, they should limit the amount and/or levels of threat in the messages.*

Two studies confirmed that DVs have the potential to improve viewers' behavioural change intentions. Given their popularity, DVs should be carefully designed in order to use them to their full potential. This research provides some guidelines that should help designers of DVs targeting health issues.

## 6 LIMITATIONS AND FUTURE WORK

We were not able to conduct in-person studies due to the COVID-19 pandemic; instead, we conducted online studies, which limited the controllability of our study. This remote setup also meant we had to rely on participants' self-reporting of their affective responses. Future studies with physiological measurements to assess affective responses will be useful to validate our findings. Furthermore, the studies were limited to negative affective responses focusing on anxiety, which may have been affected by the pandemic as participants might have been experiencing higher levels of general anxiety than usual. Additionally, the investigation of positive affect (e.g., excitement, hope) will also improve our model further. This could lead us to guidelines on how to design effective data videos using positive framing, rather than by inducing fear, especially for those who score high on neuroticism. Our studies shed light on the importance of some parts of perceived usefulness of the content in Data Videos (i.e., actionability). Future studies should investigate other dimensions of perceived usefulness in the content of DVs. With respect to personality, we followed the Big-5 personality traits. Future research might also look to other traits, such as authoritarianism [3], to understand how those aspects interact with Data Video effectiveness. We acknowledge that our results could be limited to the common health topics covered in the videos and future studies should also explore other less common health issues for which the DVs can provide their viewers with new information. Additionally, our studies had rather smaller sample sizes, and this could have led us to reject the null effects. To compensate for this issue, we provided effect sizes (which are independent from sample size issues [84]) and the descriptions of null effects in the appendices to provide a clearer picture of our results. While some effects we found in Study 1 were replicated in Study 2, another study with a greater sample size will be important. Finally, our studies looked at behaviour change on the perceptual level as opposed to actual behaviour change. A longitudinal study to explore people's actual behavioural change will be fruitful.

## 7 CONCLUSION

Data Videos (DVs) which convey rich and complex information in a short period of time, are a relatively new form of data representation that has become prominent on social media. DVs are gaining in popularity and their viewing rates are skyrocketing [12], hence they constitute a promising medium for data representation which is worth exploring. The design and creation of effective DVs require aesthetic design skills and reliable information sources. In order to move towards personalized DVs, designers also require an empirical understanding of how viewers' personalities and affective states interact with the video content and framing. Our research contributes empirical evidence about these interactions which can help video designers create DVs that are more personalized and effective. We conducted two empirical studies online, which involved participants watching health-related DVs and responding to a variety of survey instruments before, after, and in between video segments. We explored viewers' affective reactions in response to loss-framed messages in DVs and how those affective reactions were linked to the viewers' unique personalities as well as viewers' potential to consider changing their related health behaviours. Our two studies generated guidelines that DV designers can follow to create more effective, personalized health-related DVs. Our findings may also contribute to the development of novel platforms for personalized self-help and behavioural change, such as interactive DVs.

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# A LIST OF THE NINE DATA VIDEOS USED IN THE STUDY WITH THEIR RELEVANT LINKS AND SOME ADDITIONAL INFORMATION

**Table 4: List of the Data Videos used in the study, by topic**

| Title | URL | Source | Length | # Views | # Data Representations | Audio Narration |
|---|---|---|---|---|---|---|
| **Physical Activity** | | | | | | |
| Morning Exercise = Mental Health | https://www.youtube.com/watch?v=3ZBXldCxZEA | Kram Gallery | 2:12 | 373,174 | 1 | yes |
| The Importance of Intensity in Physical Activity | https://www.youtube.com/watch?v=OMn8Tq5Eyao | DocMikeEvans | 3:20 | 97,728 | 4 | yes |
| What Happens To Your Body When You Stop Exercising | https://www.youtube.com/watch?v=hQz_V9Dr8IU | Tech Insider | 2:08 | 6,339,611 | 8 | no |
| **Diet** | | | | | | |
| Sugar is Killing Us | https://www.youtube.com/watch?v=Yda8RtOcVFU | Sikuvideo | 3:23 | 1,228,701 | 3 | yes |
| What would happen if you didn't drink water? | https://www.youtube.com/watch?v=9iMGFqMmUFs | TED-ED | 4:36 | 9,027,233 | 11 | yes |
| Why eating fat won't make you gain weight | https://www.youtube.com/watch?v=47O619aXIt0 | Tech Insider | 4:43 | 346,114 | 8 | yes |
| **Sleep** | | | | | | |
| Understanding the Importance of Sleep | https://www.youtube.com/watch?v=NwJ_Xwr2irI | Tylenolofficial | 1:25 | 28,524 | 3 | yes |
| The benefits of a good night's sleep | https://www.youtube.com/watch?v=gedoSfZvBgE | Ted-Ed | 5:30 | 3,445,468 | 3 | yes |
| What causes insomnia? | https://www.youtube.com/watch?v=j5Sl8LyI7k8 | Ted-Ed | 4:47 | 1,930,075 | 6 | yes |

# B LIST OF THE DATA VIDEOS USED WITH SUMMARY DESCRIPTION AND SOME VIDEO ATTRIBUTES

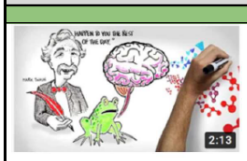
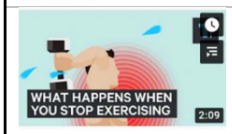
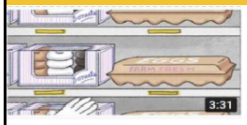
| Video | Summary | Negative Consequences | Concrete Solution | # of Infographics |
|---|---|---|---|---|
| **Physical Activity** | | | | |
|   PA1: Morning Exercise = Mental Health | The video is focusing on the importance of starting the day with physical activity.<br>Benifits of exercising in the morning as:<br>- mental capacity for handling stess triples,<br>- the brain produces chemicals (BNF and Endorphins) that clears the mind, helps in making positive decisions, minimize the discomfort and the feeling of pain andpromotes the feeling of pleasure<br>- helps with a faster metabolism, more energy and sense of accomplishment. | ✗ | ✓ | 1 |
|   PA2: The Importance of Intensity in Physical Activity | - Narrator is Dr. Mike Evans (which adds credibility and authority to the video).<br>- Video is about the importance of intensity in physical activity and they define it as "stuff that gets your heart pumping"<br>- They state that we need to perform 150 minutes of Moderate to Vigorous Physical Activity weekly.<br>- Exercise reduces heart disease and cancer, and improves mental health and the overall quality of our lives.<br>- Research has shown that higher the intensity, the better the results.<br>"Interval training is good to improve performance in a short amount of time.<br>Tips to know the intensity of the activity:<br>1. low intensity activity: if you are not sweating or not experiencing breath reate change.<br>2. Moderate activity: you feel out of breath but can still hold a conversation<br>3. Vigorous activity: you can't talk" | ✗ | ✓ | 4 |
|   PA3: What Happens To Your Body When You Stop Exercising | - The video is talking about changes and risks to the body over time as we stop exercising.<br>- The video is reporting changes that can happen over weeks to months.<br>- The video is tracking the increase in the time needed to finish a 5k run (starting at 20 min when physically active, increase of 1 min after 2-3 weeks and 3 minutes longer after 5-7 weeks.<br>- The video is also showing the dectrease in the level of VO2 max that is responsible for delivering oxygen to generate energy for muscles as the no exercise period increases. As VO2 max decreases, muscle cells become smaller and the fat cells are become bigger. | ✓ | ✗ | 8 |
| **Diet** | | | | |
|   Diet1: Sugar is Killing Us | - The video is talking about the dangers of sugar.<br>- Scientists are saying sugar is toxic. It turned out that sugar is not only not healthy but it is dangerous.<br>- High fructose in sugar can harm the body in various ways and causes lots of health issues.<br>- However it is not easy to cut down on sweets as high fructose corn syrup are now added to foods that you never expect.<br>- A recent study found the 80% of food in America contain added sugar.<br>- At the end, the video is suggesting that the solution is to educate consumers not to buy produscts with added sugar which will affect the sales of such producs. | ✓ | ✗ | 3 |
|   | - The video is about the role of water in the human body and how much do we need to drink to stay healthy.<br>- Water cushion and lubricate joints, regulate temperature and nourish the brain and spinal cord.<br>- Each day our bodies lose 2-3 liters of water through sweat, urine and bowel movements and even from breathing. We need to drink water to compensate for this loss.<br>- The amount of daily water intake we need ranges between 2.5-3.7 L for men and 2-2.7 L for women depending on theweight and environment.<br>- Benifits of being well hydrated:<br>**lower the chance of stroke, manage diabetes, reduce the risk of certain types of cancer** | ✓ | ✓ | 11 |
|   Diet3: Why eating fat won't make you gain weight? | - This video is focused on the benifits of good fats and how they are not associated with weight gain while carbs are the real issue.<br>- Research shows that low fat diets do not aid in weight loss or reducing the risk of disease compared to high-fat diet and the refined carbs might be the real issue.<br>- Good fats are very important for the body to function properly.<br>- Monosaturated fats are found in olive oil and avocados and they reduce inflammations and levels of LDL or bad cholesterol in the blood.<br>- Polyunsaturated fats are found in fish are very useful; Omega-3 fatty acids decrease blood pressure and increase DHL or good Cholesterol and protects against heart disease.<br>- Studies showed that full fat dairy is healthier than reduced fat as full fat dairy is found to be associated with a lower risk of type 2 diabetes | ✓ | ✓ | 8 |
| **Sleep** | | | | |
|   Sleep1: Understanding the Importance of Sleep | This video is short and to the point. It explains the importance of getting good sleep, how much sleep do we need and the dangers of not getting enough sleep.<br>Almost half of the video is dedicated to listing annoying and worrying threats of inadequate sleep (e.g. you will look older, you will get fat, you will develop cardiovascular disease, etc.) | ✓ | ✗ | 3 |
|   Sleep2: The benefits of a good night's sleep | - The video is talking about the importance of sleep for memory consolidation.<br>- It starts by puting the viewers in an imaginary situation where they have a test in 8 hours followed by a piano recital and you are not feeling ready yet. You can drink a cup of coffee and spend some time studying and practicing but the narrator assures that it is better to put everything away and sleep.<br>- The video contains a lot of scientific informations and terms and refers to several scientific studies related to the brain and the process of memory consolidation. | ✓ | ✓ | 3 |
|   Sleep3: What causes insomnia? | - The video focuses on insomnia, its symtoms, reasons and provides some solutions.<br>- unlike healthy sleepers, during their sleep, insomniac exoerience high metabolism which exhausts their bodies and brain making them wake in a state exhaustion, stress and confusion.<br>- Insomnia's chemical mechanisms are similar to anxiety attacks found in people experiencing depression and anxiety and accordingly suffering from insomnia increases the risk of suffering from depression and anxiety. | ✓ | ✓ | 6 |

**Figure 8: List of all videos with summary description and some video attributes.**

# C NOMOLOGICAL NETWORK ON INFORMATION USEFULNESS IN DATA VIDEOS

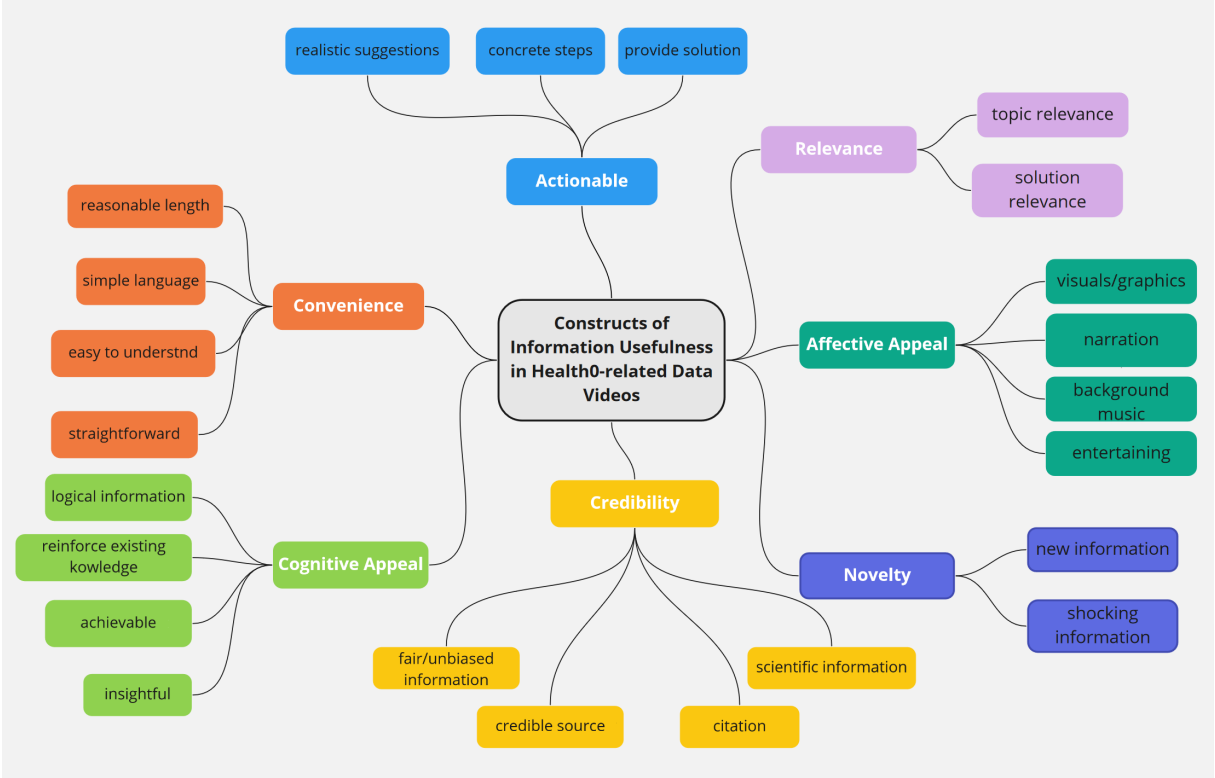



**Figure 9: Nomological network of the dimensions of Information usefulness in data videos**

## D VIDEO VIEWING EXPERIENCE

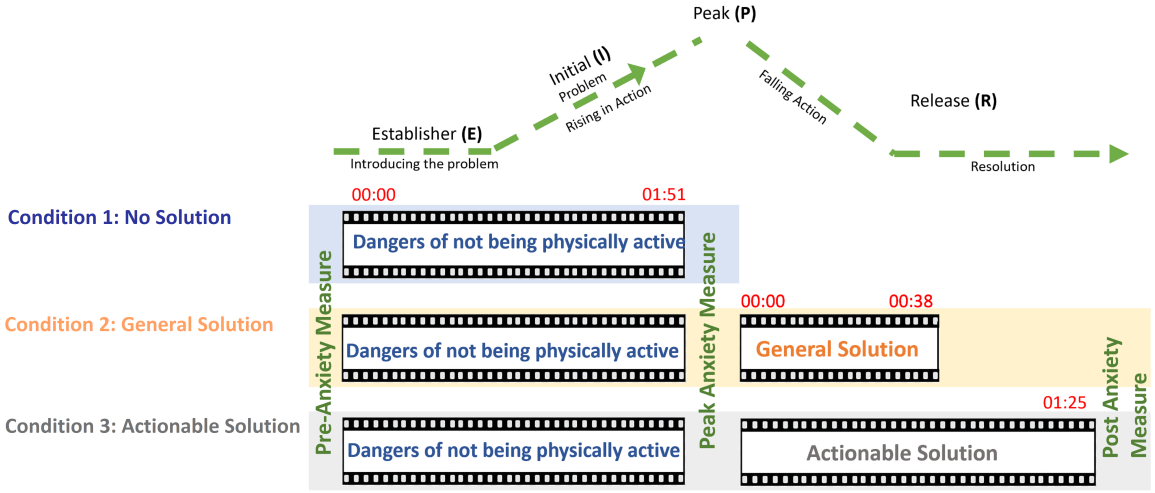



**Figure 10: Participants were randomly assigned to one of the three video conditions:**
**1. In the *No Solution* condition, participants watched one video segment that covered the dangers of not being physically active then answered the Affective state questions.**
**2. In the *General Solution* Condition, participants watched 2 video segments; the first segment covered the dangers of not being physically (identical to condition 1), then they answered the affective state question, finally they watched the second video segment that introduced a general solution.**
**3. In the *Actionable Solution* Condition, participants watched 2 video segments; the first segment covered the dangers of not being physically (identical to condition 1 and 2), then they answered the affective state question, finally they watched the second video segment that introduced an actionable solution.**

# E ACTIONABILITY SCALE

**Table 5: Items to measure the videos' actionability**

| Please report you thoughts about the video. |
|---|
| Generally, the video provided solution(s) to the discussed issue. |
| Generally, the video provided concrete steps to address the problem. |
| Generally, the video provided easy to understand solutions |
| Generally, people would be capable of implementing the proposed solutions. |
| Generally, people would have the required resources (time, space, etc.) to carry out the suggestions in the video. |
| Generally, the video provided unrealistic advice. (R) |
| After watching the video, people would know exactly what to do. |

(R) = item is reverse-scored.
*A Likert scale (1: Strongly Disagree to 7: Strongly Agree) is used.*

# F ADDITIONAL ANALYSES:

Since our sample sizes are smaller, we provide results for non-significant effects so the readers can consider potential false negatives. Note when appropriate, effect sizes are provided throughout to guide the interpretation as they are independent of sample size [84].

## F.1 Study 1

**Re: Predictors of GPP (Personality traits & Content Appraisal variables)**: the below table shows the excluded variables in the regression analysis.

**Excluded Variables**

| | Beta In | t | Sig. |
|---|---|---|---|
| Extraversion | 0.095 | 1.38912 | 0.169 |
| Agreeable | 0.118 | 1.76777 | 0.081 |
| Conscientious | -0.034 | -0.4866 | 0.628 |
| Openness | 0.012 | 0.18103 | 0.857 |
| Information Clarity | -0.024 | -0.2655 | 0.791 |
| Information Importance | 0.116 | 1.31965 | 0.191 |

**Figure 11: Excluded variables in regression analysis exploring personality traits variables as well as content appraisal variables as predictors of GPP.**

**Personality Traits & Negative Affect:** the below table is the correlation Matrix showing the correlations between personality traits and negative affect.

| | | Extraversion | Agreeable | Conscientious | Neurotic | Openness | Negative Affect |
|---|---|---|---|---|---|---|---|
| | Correlation Coefficient | 1 | 0.13069 | 0.042688207 | -.234* | 0.004796044 | -0.163464157 |
| | Sig. (2-tailed) | | 0.254085 | 0.710567239 | 0.039031982 | 0.966758678 | 0.152715171 |
| Extraversion | N | 78 | 78 | 78 | 78 | 78 | 78 |
| | Correlation Coefficient | 0.13068967 | 1 | 0.169148333 | -.276* | 0.021052953 | -0.170454635 |
| | Sig. (2-tailed) | 0.25408461 | | 0.138753383 | 0.014272173 | 0.854834928 | 0.135685443 |
| Agreeable | N | 78 | 78 | 78 | 78 | 78 | 78 |
| | Correlation Coefficient | 0.04268821 | 0.169148 | 1 | -.398** | 0.049577655 | -.363** |
| | Sig. (2-tailed) | 0.71056724 | 0.138753 | | 0.000304695 | 0.666429123 | 0.001097303 |
| Conscientious | N | 78 | 78 | 78 | 78 | 78 | 78 |
| | Correlation Coefficient | -.234* | -.276* | -.398** | 1 | -0.139575989 | .594** |
| | Sig. (2-tailed) | 0.03903198 | 0.014272 | 0.000304695 | | 0.222929266 | 9.9648E-09 |
| Neurotic | N | 78 | 78 | 78 | 78 | 78 | 78 |
| | Correlation Coefficient | 0.00479604 | 0.021053 | 0.049577655 | -0.139575989 | 1 | -0.168304717 |
| | Sig. (2-tailed) | 0.96675868 | 0.854835 | 0.666429123 | 0.222929266 | | 0.140762323 |
| Openness | N | 78 | 78 | 78 | 78 | 78 | 78 |
| | Correlation Coefficient | -0.16346416 | -0.170455 | -.363** | .594** | -0.168304717 | 1 |
| | Sig. (2-tailed) | 0.15271517 | 0.135685 | 0.001097303 | 9.96E-09 | 0.140762323 | |
| Negative Affect | N | 78 | 78 | 78 | 78 | 78 | 78 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

**Figure 12: Correlations between personality traits and negative affect**

## F.2 Study 2

**Re: Perceived actionability ( section 4.5.4) :** below, we list results of all pairwise conditions comparison using Mann-Whitney U test (including null effects).

- No solutions condition ($n$ = 25; Mean ranking was 22.70) vs. General solutions condition ($n$ = 29; Mean ranking was 31.64). $U$ = 242.5, $Z$ = -2.09, $p$ = .04 (With Holm-Bonferroni, the alpha was set at .025.) , $r$ = .28, a small effect.
- General solutions condition ($n$ = 29; Mean ranking was 25.71) vs. Actionable solutions condition ($n$ = 28; Mean ranking was 32.41). $U$ = 310.50, $Z$ = -1.53, $p$ = .13 (With Holm-Bonferroni, the alpha was set at .05), = .20, a small effect.
- No solutions condition ($n$ =25; Mean ranking was 19.88) vs. Actionable solutions condition ($n$ = 28; Mean ranking was 33.36). $U$ = 172.00, $Z$ = -3.18, $p$ = .001* (With Holm-Bonferroni, the alpha was set at .0167), $r$ = .44, a medium effect.

**Re: Usefulness ( section 4.5.4) :** below, we list the results of all pairwise comparisons between our video conditions in terms of perceived usefulness using Mann-Whitney U tests.

- No solutions condition ($n$ = 25; Mean ranking was 23.98) vs. General solutions condition ($n$ = 29; Mean ranking was 30.53). $U$ = 274.50, $Z$ = -1.578, $p$ = .115 (With Holm-Bonferroni, the alpha was set at .025), $r$ = .21 which is a a small effect .
- General solutions condition ($n$ = 29; Mean ranking was 26.19) vs. Actionable solutions condition ($n$ = 28; Mean ranking was 31.91). $U$ = 324.50, $Z$ = -1.387, $p$ = .166 (With Holm-Bonferroni, the alpha was set at .05), $r$ = .18 which is a a small effect .
- No solutions condition ($n$ =25; Mean ranking was 21.52) vs. Actionable solutions condition ($n$ = 28; Mean ranking was 31.89). $U$ = 213.00, $Z$ = -2.555, $p$ = .011* (With Holm-Bonferroni, the alpha was set at .0167), $r$ = .35, a medium effect.

**Re: Actionability, Anxiety, & GPP (section 4.5.4) :** below, we list the results of all pairwise comparisons in reducing the anxiety level using Mann-Whitney U test.

- No solutions condition ($n$ = 25; Mean ranking was 23.50) vs. General solutions condition ($n$ = 29; Mean ranking was 30.95). $U$ = 262.50, $Z$ = -2.252, $p$ = .024 (With Holm-Bonferroni, the alpha was set at .025), $r$ = .31 which is a medium effect .
- General solutions condition ($n$ = 29; Mean ranking was 28.71) vs. Actionable solutions condition ($n$ = 28; Mean ranking was 29.30). $U$ = 397.50, $Z$ = -.14, $p$ = .89 (With Holm-Bonferroni, the alpha was set at .05), $r$ = .02 which is a small effect .
- No solutions condition ($n$ = 25; Mean ranking was 22.00) vs. Actionable solutions condition ($n$ = 28; Mean ranking was 31.46). $U$ = 225.00, $Z$ = -2.872, $p$ = .004 (With Holm-Bonferroni, the alpha was set at .0167), $r$ = .39 which is a medium effect .

**Re: Personality traits and Negative Affect (section 4.5.4):** Although the exploration of personality traits was not central to Study 2 as it focused on the investigation of the solution for information usefulness, below we provide additional analyses we conducted.

We explored whether personality traits could predict experienced negative affects with linear regression with personality traits as predictors, using the stepwise method. Only neuroticism ($\beta$ = .37; $p$ = .001) and conscientiousness ($\beta$ = -.34; $p$ < .001) and remained in the model ($R^2_{adj}$ = .36, $p$ < .001). Please see below for the excluded variables.

**Excluded Variables**

| | Beta In | t | Sig. |
|---|---|---|---|
| Extroversion | .108c | 1.304 | 0.195 |
| Agreeable | .042c | 0.455 | 0.650 |
| Openness | .004c | 0.045 | 0.964 |

**Figure 13: Excluded variables in regression analysis exploring personality traits as predictors of experienced levels of negative affect.**