Are you thinking about friends or money? Spontaneous thought contents reveal the value of social relationships for happiness

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Abstract

Spontaneous thoughts are useful in exploring one's mind, as they reflect ongoing experiences and value systems. In the present study, we investigated how the spontaneous thought contents are associated with happiness. To capture individuals' thoughts, we utilized a Free Association Semantic Task (FAST) where participants (n = 210) generated chains of concepts starting from given seed words. The self-generated concepts were analyzed with a natural language processing (NLP) approach where each concept was represented by a vector of 300 semantic features. Based on the extensive literature supporting the significance of social relationships for happiness, we tested whether happy individuals think more about friends. Participants with higher subjective well-being, in particular those with more frequent positive affect, generated concepts semantically more similar to 'friend,' and showed a trend of aligning their thoughts with 'friend' over time. Interestingly, the semantic associations with 'money' were not linked to subjective well-being. These results were replicated and generalized in an independent sample (n = 350). Furthermore, in a dilemma task where participants had to indicate the degree of income increase that would make them willing to accept a lucrative job offer at the cost of sacrificing their close relationships, the prevalence of friend-related concepts among happier participants predicted their tendency to value close relationships over monetary gains. By construing individuals' minds with a novel computational approach, our work elucidates how the value of social relationships is manifested in spontaneous thought contents and everyday decisions, which may consequently contribute to happiness.

Keywords

Spontaneous thoughts, natural language processing, subjective well-being, social relationships, decision-making

Significance

Spontaneous thoughts are a window into one's mind, reflecting ongoing experiences and value systems. By combining FAST and NLP, we access these thoughts to investigate whether happier individuals think more about friends, as indicated by consistent evidence for the importance of positive social relationships in subjective well-being. We found that the self-generated thought contents of individuals with higher subjective well-being, particularly those with more frequent positive affect, had stronger semantic association with 'friend,' but not with 'money.' Such thought patterns predicted the degree to which individuals value social relationships over monetary gains. Our work offers profound insights into how the significance of social relationships to happiness can be manifested in individuals' minds and contribute to their decisions in everyday life.

Introduction

In the pursuit of understanding the intricate human mind, a compelling way of exploration is to examine the contents of spontaneous thoughts. Recent evidence suggests that spontaneous thoughts are not random but self-relevant in nature, mirroring one's current mental states, past and ongoing experiences, and future goals, as well as personal significance and values, thus offering a unique lens through which to understand our minds (1-7). The present study aims to understand how the specific thought contents that occupy individuals' minds are related to happiness. Specifically, based on an extensive body of literature supporting the importance of social relationships for happiness, we investigate whether happier individuals are more inclined to think about social connections and friendships compared to less happy individuals.

Social connections, as basic human needs (8-10), are not only essential for human survival (11, 12) but also crucial for one's well-being (13-18). Indeed, evidence shows that very happy individuals have richer and stronger positive social relationships with others compared to those who are less happy (19, 20). Not only social relationships but also material wealth has been considered relevant to happiness in modern society (21-25). Although material wealth, often measured as income, is correlated with happiness, the strength and the nature of this relationship (e.g., whether linear or curvilinear) vary across different baselines and dimensions of well-being (26, 27). It has been specifically shown that cognitive well-being, such as life satisfaction, increases with income; however, findings about emotional well-being, such as positive and negative affect, are inconsistent (21, 23, 26). Furthermore, the excessive pursuit of material values often appears negatively associated with happiness (28, 29). Together, previous findings imply that, while social relationships are consistently related to happiness, the relation between money and happiness could be more complex and inconsistent.

To further elucidate how happiness is associated with social relationships and money, we access and construe individuals' stream of thoughts with a cutting-edge computational approach. By combining Free Association Semantic Task (FAST), a free-association-based thought sampling method (5, 6) and Natural Language Processing (NLP) with Word2vec (30), a technique that converts words into vectors to capture semantic associations of a given chain of thoughts, we analyzed the contents and patterns of thoughts and sought to answer the following questions. First, how are the self-generated thoughts about friends or money related to happiness, namely subjective well-being (SWB)? Second, which components of SWB, including life satisfaction (LS), positive affect (PA), and negative affect (NA), are more closely associated with the thoughts about friends or money? Third, would the self-generated thought contents predict everyday decisions involving a trade-off between social relationships and monetary gains?

We recruited 210 participants (English-speaking residents of the US/UK; 114 males and 96 females, mean age = 28.367) for a main study, which consisted of two sessions. In the first session, the participants filled out questionnaires to measure SWB (31), including PA, NA,

and LS (32-35). Subsequently, the participants performed the FAST, in which they were asked to generate 30 consecutive concepts from each given seed word—"key" serving as a neutral seed word and "friend" and "money" as priming seed words—resulting in a total of 90 concepts generated for each participant. Next, the participants evaluated the valence, importance, and other- vs. self-relevance (36) of the concepts that they generated in the FAST. With these measures, we explored how the concepts generated by happier participants can be characterized (e.g., more positive and other-relevant). The participants were re-invited to the second session of the main study within 3 days after the first session. During this session, they conducted a decision task in a realistic dilemma where they had to indicate the degree of income increase that would make them willing to accept a lucrative job offer at the cost of sacrificing their close relationships. Here, we tested whether the self-generated thought contents could predict participants' decisions placing greater value on social relationships over monetary gains.

Each of the self-generated concepts was converted into a vector of 300 semantic features so that we could quantify the semantic similarity and convergence of the self-generated concepts to 'friend' or 'money' using cosine similarity (37) and word mover's distance (WMD) (38). The two target concepts of 'friend' and 'money' were selected based on their representative nature of the interpersonal and monetary domains of life that are most relevant to happiness research (39-41). We expected that the way these two concepts are represented within one's mental landscape would vary, contributing to happiness in different ways for different people. This perspective is supported by previous research on spontaneous thoughts, which suggests that concepts arising from everyday thoughts are tied to an individual's unique concerns and experiences, rather than general concepts shared universally among people (4-7). We hypothesized that the self-generated thoughts of happier individuals would be more similar to 'friend,' compared to those generated by less happy individuals. After testing this idea, we conducted confirmatory analyses and replicated our findings with an independent sample of 350 participants (Korean; 171 males and 179 females, mean age = 22.780) from existing data collected prior to the main study for a different purpose (6, 42).

Results

In this section, we report the results of the following analyses. We first examine how SWB and its sub-components, including LS, PA, and NA, are linked to *i*) the similarity of concepts participants generated to either 'friend' or 'money' (i.e., cosine similarity and WMD) and *ii*) the extent to which these concepts become more similar to either 'friend' or 'money' over time (i.e., convergence). Hereafter, double quotes indicate the seed words, while single quotes denote the target concept, unless specified otherwise. Then, we explore the relationship between the SWB measures and participants' evaluations of the valence, importance, and other- vs. self-relevance of the self-generated concepts. Lastly, we test whether these thought patterns predict individuals' choices between social relationships and monetary gains in the realistic dilemma (see Fig. 1 for an overview of our study design). All descriptive statistics are presented in Tables S1 and S2 for the main and independent samples, respectively, in the supporting information.

Self-generated thoughts of individuals with higher SWB are more similar to 'friend'

We first examined whether SWB, including PA, NA, and LS, is associated with the similarity (i.e., cosine similarity and WMD) of self-generated thoughts to the target words (i.e., 'friend' and 'money'). Note that the variable of our major interest is the average similarity scores that reflect the overall similarity regardless of the seed words, while we additionally report the results for the similarity scores separately calculated for different seed words (Fig. 2A to 2C).

In line with our expectation, participants with greater SWB generated concepts with higher cosine similarity to 'friend' ($b = 0.001$, $t_{203} = 2.505$, $P = 0.013$; Fig. 2A). A multiple regression analysis with PA, NA, and LS as predictors and the average cosine similarity to 'friend' as an outcome variable showed that PA, in particular, was significantly correlated with the cosine similarity. Overall, the concepts generated by participants with greater PA exhibited higher similarity to 'friend' ($b = 0.002$, $t_{201} = 2.942$, $P = 0.004$; Fig. 2A). Additional analyses of the cosine similarity score for each seed word revealed a consistent positive relationship between PA and the cosine similarity to 'friend' when the seed word was "friend" ($b = 0.004$, $t_{201} = 3.767$, $P < 0.001$; Fig. 2A). Cosine similarity to 'money' was not associated with any of the SWB measures (Fig. 2A). Detailed results related to the cosine similarity are shown in Tables S3-1 & S3-2.

The analyses on the WMD from the target words (i.e., 'friend' or 'money') yielded consistent results. Participants with greater SWB generated concepts with shorter average WMD from 'friend,' in other words, closer to 'friend' ($b = -0.001$, $t_{203} = -2.252$, $P = 0.025$; Fig. 2B). A multiple regression analysis with PA, NA, and LS as predictors and the average WMD score as an outcome variable revealed that greater PA was significantly associated with a shorter distance from 'friend' ($b = -0.001$, $t_{201} = -2.935$, $P = 0.004$; Fig. 2B). A similar pattern was observed when we analyzed the WMD calculated for the concepts generated from the seed word "friend" ($b = -0.003$, $t_{201} = -3.610$, $P < 0.001$; Fig. 2B). We found no significant association between any of the SWB measures and the WMD from 'money' (Fig. 2B). Unlike PA, neither NA nor LS was associated with the cosine similarity or the WMD (Fig. 2B).

Detailed results related to the WMD are shown in Tables S4-1 & S4-2.

To confirm and generalize our findings, we analyzed the independent sample of Korean participants. Replicating the results from our main sample of the US/UK participants, we found that the concepts generated by participants with greater SWB had higher cosine similarity to 'friend' ($b = 0.002$, $t_{324} = 2.726$, $P = 0.007$), whereas cosine similarity to 'money' was not correlated with SWB ($b < 0.001$, $t_{324} = -0.115$, $P = 0.909$). A multiple regression analysis with PA, NA, and LS as predictors further revealed that PA was positively associated with similarity to 'friend' ($b < 0.001$, $t_{322} = 2.169$, $P = 0.031$). Analyses on the WMD measures with the independent sample showed the same patterns. Participants with greater SWB generated concepts with shorter distances from 'friend' ($b = -0.002$, $t_{324} = -2.910$, $P = 0.004$). In the multiple regression analysis with PA, NA, and LS, greater PA significantly predicted a shorter distance from 'friend' ($b < 0.001$, $t_{322} = -2.021$, $P = 0.044$). Again, no significant correlations with any of the SWB measures were found for similarity to 'money'. Neither NA nor LS was correlated with the cosine similarity or the WMD in the independent sample, consistently suggesting the specific involvement of PA in the similarity of self-generated thought contents to 'friend.' Detailed results related to cosine similarity and WMD of the independent sample are shown in Tables S5 & S6, respectively.

Self-generated thoughts of individuals with higher SWB are more likely to converge to 'friend'

We further examined whether happier participants' self-generated thoughts are more inclined to converge to 'friend' or 'money.' The convergence score was calculated for each individual based on a linear regression slope of trial-by-trial cosine similarity values interpolated from the first trial to the last trial (see Materials and Methods for details). The greater convergence score indicates an increasing trend in the similarity score toward a target word. The results showed that participants with greater SWB exhibited greater convergence to 'friend' ($b < 0.001$, $t_{202} = 2.492$, $P = 0.014$; Fig. 2C). A multiple regression analysis with PA, NA, and LS as predictors revealed that PA was significantly associated with the convergence to 'friend' ($b < 0.001$, $t_{200} = 2.389$, $P = 0.018$; Fig. 2C). Further analyses with the convergence score separately calculated for each seed word revealed that PA was positively correlated with the convergence to 'friend' when the seed word was "friend" ($b < 0.001$, $t_{200} = 3.358$, $P = 0.003$; Fig. 2C). PA showed a significant positive association with the convergence to 'friend' even when the seed word was "money" ($b < 0.001$, $t_{200} = 2.165$, $P = 0.048$; Fig. 2C). None of the convergence scores to 'money' were related to SWB, PA, or NA, but we unexpectedly found a significant association between LS and the convergence to 'money' when the seed word was "money" ($b < 0.001$, $t_{200} = 2.440$, $P = 0.048$; Fig. 2C). Detailed results related to the convergence are shown in Tables S7-1 & S7-2.

We again performed the identical analyses with the independent sample of Korean participants and found consistent results (see Fig. 2D for all summarized results of the cosine similarity, WMD, and convergence). Participants with higher SWB showed greater tendency to align their self-generated thoughts to 'friend' as the trials progressed ($b < 0.001$, $t_{323} =$

2.889, $P = 0.004$). This effect was especially evident for PA ($b < 0.001$, $t_{321} = 2.487$, $P = 0.013$) in the multiple regression analysis with PA, NA, and LS as predictors. Detailed results related to the convergence of the independent sample are shown in Tables S8-1 & S8-2.

Evaluations of the self-generated concepts vary with SWB

Next, we examined how SWB is linked to the evaluations of self-generated concepts. Overall, we found that higher SWB was associated with more positive evaluations ($b = 0.110$, $t_{203} = 5.332$, $P < 0.001$; Fig. 3A) and greater perceived relevance to others than to oneself ($b = 0.082$, $t_{203} = 3.354$, $P = 0.001$; Fig. 3A), irrespective of the seed words. Figure 3B illustrates this relationship with word cloud examples of the self-generated concepts from four representative participants with varying levels of SWB. Then, we performed multiple regression analyses on the effects of PA, NA, and LS on the valence, importance, and other- vs. self-relevance ratings. The results showed that PA was significantly correlated with the valence rating ($b = 0.048$, $t_{201} = 2.315$, $P = 0.022$; Fig. 3A) such that participants with greater PA evaluated the self-generated concepts more positively. The multiple regression analysis on the other- vs. self-relevance ratings revealed that participants with greater NA were more likely to evaluate the self-generated words as more relevant to self than others ($b = -0.050$, $t_{201} = -2.398$, $P = 0.017$; Fig. 3A).

In further exploration with the evaluation scores of the self-generated words from different seed words, we found that PA was significantly linked to more positive assessments of the self-generated concepts when the seed word was "friend" ($b = 0.093$, $t_{201} = 3.365$, $P = 0.003$; Fig. 3A), while NA and LS were not associated with the valence rating. For the other- vs. self-relevance rating, the effect of NA was significant when the seed words were "money" ($b = -0.061$, $t_{201} = -2.381$, $P = 0.027$; Fig. 3A) and "key" ($b = -0.067$, $t_{201} = -2.973$, $P = 0.009$; Fig. 3A), while no significant effects were found for PA or LS. The importance ratings were not associated with any of the SWB measures (Fig. 3A). Detailed results related to the evaluation scores are shown in Tables S9-1 & S9-2.

Self-generated thoughts about 'friend' predict individuals' prioritization of social relationships over monetary gain

To examine whether the self-generated thought patterns could predict individuals' choices, we presented a realistic dilemma in which the values of social relationships and monetary gains conflict. In this scenario, participants were asked to indicate the degree of income increase that would make them willing to accept a lucrative job offer at the cost of sacrificing their close relationships. The data showed that participants who generated concepts similar to 'friend' responded that they would need greater income increase, in other words, placed greater value on social relationships. Specifically, this preference for social relationships over monetary gains was correlated with greater cosine similarity to 'friend' ($b = 25.220$, $t_{185} = 2.399$, $P = 0.017$; Fig. 4A) and shorter WMD from 'friend' ($b = -30.413$, $t_{185} = -2.497$, $P = 0.013$; Fig. 4A). Interestingly, this pattern was especially evident for the seed word "money," where the cosine similarity to 'friend' showed a significant influence ($b = 18.625$, $t_{185} = 2.648$, $P = 0.027$; Fig. 4A), when we analyzed the similarity measures calculated separately for

different seeds. A marginal effect was also observed with WMD from 'friend' for the seed word "money" (b = -19.364, t_{185} = -2.367, P = 0.057; Fig. 4A), when analyzing the similarity measures for different seeds. Detailed results related to the dilemma task are shown in Tables S10-1 to S10-3.

To ensure the predictive power of our analyses, we also performed a leave-one-out cross-validation (LOOCV) analysis. When we compared the mean squared errors (MSEs) from the LOOCV with those from our initial regression analyses using the full dataset to evaluate the predictive performance of our regression models, none of the MSEs from the full dataset significantly deviated from individual MSEs or exceeded one standard deviation from the average MSEs, lending support to the validity of our models (Fig. 4B & Table S10-4).

Finally, we examined whether the effects of SWB on participants' prioritization of social relationships over monetary gains were mediated by their self-generated thought patterns. We found that those with higher SWB prioritized social relationships over monetary gains, and this relationship was mediated by the overall greater similarity of the self-generated concepts to 'friend' (indirect effect of cosine similarity: b = 0.030, SE = 0.020, 95% CI = 0.0015 to 0.0757, Fig. 4C; indirect effect of WMD, b = 0.029, SE = 0.019, 95% CI = 0.0011 to 0.0732, Fig. S1A). When analyzing PA, NA, and LS separately, the same mediational results were observed when PA was entered into the model as the predictor (indirect effect of cosine similarity: b = 0.024, SE = 0.014, 95% CI = 0.0012 to 0.0544; indirect effect of WMD, b = 0.024, SE = 0.013, 95% CI = 0.0028 to 0.0530; Fig. S1B). For results of NA and LS, see Fig. S1C & S1D.

Discussion

The present study investigated the relationship between self-generated thought contents and happiness by utilizing a cutting-edge behavioral paradigm and analytic framework, namely FAST and NLP. With this novel approach, we accessed and quantified participants' thoughts about 'friend' and 'money' to examine how these thought contents relate to their SWB and decisions involving a trade-off between social relationships and monetary gains. Our findings suggest that the value of social relationships for happiness is intrinsically reflected in spontaneous thoughts that are rooted in one's semantic networks.

Consistent with previous evidence that happier individuals are often characterized by positive relationships and rich social resources (13-20, 40), our study found that individuals with higher SWB were more likely to generate thoughts related to the concept of 'friend.' This pattern held across our semantic similarity measures, including cosine similarity, WMD, and convergence scores. Furthermore, these results were corroborated and extended in the independent sample of Korean participants, who used different seed words and a different language from those in our main sample of the US/UK participants. Given that self-generated thoughts arise from episodic and semantic memory supported by similar neural systems (4, 43), our results may suggest that happier individuals accumulate more pleasurable experiences shared with others, which are stored in episodic memory and can be more easily drawn upon as resources for spontaneous thoughts.

One of the important findings of the present study is that among the subcomponents of SWB, PA was particularly associated with self-generated thoughts about 'friend.' This result aligns well with prior research that demonstrates a robust link between positive affect and positive social relationships (40, 44-46). Theories suggest that positive affect deepens social bonds by enhancing intimacy and harmony (47) and buffering the impact of negative experiences (48). The role of positive relationships in fostering positive affect has also been suggested by attachment theory (49) and the self-expansion model (50). Moreover, the broaden-and-build theory posits that PA not only strengthens social connections but also initiates a virtuous cycle, where rich social resources amplify positive emotional states (51). Overall, the existing literature indicates the reciprocal link between PA and interpersonal relationships (45).

The prevalence of friend-related thoughts among those with greater PA, as found in the present study, seems to reflect such a bidirectional relationship. That is, those experiencing greater PA in their daily lives may be more likely to recall relationship-related concepts and extract positive values from them, thereby creating a virtuous circle to reinforce their positive affective experiences. Interestingly, the alignment of friend-related thoughts over time persisted even when they were initially prompted with the seed word "money." This suggests that for those with greater PA, social aspects may be broadly embedded in their semantic networks, extending beyond mere material considerations to underscore the role of sharing positive social experiences in fostering happiness (52). Together, our findings not only confirm the well-established link between happiness, especially PA, and social relationships but also enrich our understanding of how the value of social relationships is cognitively

represented in happier individuals' stream of thoughts.

Notably, the value of social relationships was instantiated in the decision-making task. We found that participants' prevalence of friend-related thoughts predicted their choices involving the tradeoff between social relationships and monetary gains. This finding highlights the crucial role of deeply rooted conceptual associations in shaping real-life behavior and decision-making. This pattern was also observed among those with higher SWB, especially those with higher PA, as revealed in our mediation analyses. Previous research has shown that those with higher SWB often choose social events over financial or academic gains, leading to more favorable hedonic outcomes (34, 35). However, the specific processes guiding these choices have been unclear. Moreover, while extensive literature has documented the importance of social relationships across various life domains—including mental and physical health (53-55), workplace performance (56), mortality rates (57), and cognitive functions (58, 59)—little has been known about the conceptual, semantic underpinnings of preferences for social relationships over monetary gains in decision-making contexts. Our study addresses this gap by showing that self-generated thought contents can reveal the values placed on social relationships.

Interestingly, while the thoughts about 'friend' consistently correlated with happiness, those of happier individuals showed no significant semantic association with the concept of 'money.' This disparity may arise because money is a secondary reinforcer, which gains its value via learned associations with a primary reinforcer (60), unlike the inherently rewarding nature of social interactions (10, 61). Specifically, as the reward signals embodied in positive events are often prioritized in memory (62, 63) and the value ascribed to money is contingent upon its association with other rewarding experiences, the connection between happiness and money-related concepts could be relatively limited. Consequently, the levels of happiness might not necessarily translate into the concept recalls related to money, implying the complex and nuanced ways in which material resources contribute to happiness. Indeed, previous findings on the relationship between money and happiness across SWB subcomponents are inconsistent (21, 26). Similarly, most of the correlations between money-related thoughts and SWB were not significant in the present study. Yet, participants' thoughts increasingly aligned with 'money' in response to the seed word "money" as their LS increased, which is in line with existing literature (21, 64). Another possible reason for the disparity is the smaller individual variations in thoughts about 'money' compared to those about 'friend.' In our data, individual variations in thoughts about 'friend' were more pronounced than those about 'money' across most variables (see Fig. S2). This may indicate that social relationships occupy a more divergent and uniquely personalized space in people's minds, leading to more idiosyncratic representations of their social experiences when compared to monetary ones.

Not only did we examine how participants' thoughts are represented in objective vector space, but we also analyzed them using traditional subjective ratings. First, we found that participants with higher SWB and PA more positively evaluated the self-generated concepts.

This result could be attributed to the nature of the concepts themselves, such that the concepts closer to 'friend' were more positively evaluated than the concepts closer to 'money,' rather than to the general positivity of happier participants. Indeed, we found significant correlations between overall valence scores and cosine similarity to (r = 0.185, P = 0.007) and WMD from 'friend' (r = -0.149, P = 0.030) but not 'money' (cosine similarity, r = 0.096, P = 0.167; WMD, r = -0.037, P = 0.597). These findings provide further support that interpersonal relationships and the positive values attributed to them play a crucial role in happiness. Second, participants with higher SWB and lower NA rated the self-generated concepts as more relevant to others than to themselves. This finding is particularly interesting considering the association between other-oriented behaviors and happiness (65-68). Extended engagement or interest in others, as reflected in one's semantic networks, might serve as a starting point from which social connections are strengthened, thereby benefiting SWB. This view reinforces the idea that happiness involves more than just individual experiences; it's also about how we connect with and consider those around us. Conversely, greater NA seems to be associated with self-focused thoughts, in line with previous findings that negative affect narrows one's attention to personal needs and a more inward-oriented thought process (69). It is worth noting that, in our data, higher cosine similarity to 'money' was correlated with lower other- vs. self-relevance ratings (r = -0.149, P = 0.031). In other words, the thoughts related to 'money' are self-centered, which may partially explain the less pronounced relationship between the money-related thoughts and happiness.

Lastly, our study, leveraging FAST combined with NLP, offers unique methodological strengths by quantifying the subtle semantic relationships of individuals' thoughts. This approach enables a more objective and comprehensive analysis of specific thought contents and patterns, providing novel insights into the cognitive structures that underpin happiness and behavior that conventional methods may not fully capture. Future research could extend our findings by exploring these relationships across different populations and life domains, using various seed and target concepts to offer a more complete view of the relationship between semantic processes and happiness. Additionally, our approach could be useful in exploring how individuals' conceptual changes affect their happiness and behavioral changes, and vice versa.

Overall, the present study paves a new way for quantitatively assessing self-generated thought contents and their implications for happiness and decision-making. Our findings suggest that happier individuals think more about interpersonal relationships, influencing their decisions to favor social over monetary values. Furthermore, their positive and other-relevant perceptions of self-generated concepts highlight the role of emotional valence and an extended interest in or shared experiences with others in happiness. Together, by adopting an innovative approach, our work holds great theoretical importance for understanding how the value of social relationships for happiness is reflected in individuals' minds, with real-life implications by showcasing how it manifests in everyday decisions.

Materials and methods

Participants

All participants of the main data set were recruited through Prolific (https://www.prolific.com/). Based on a priori power analysis using G*Power (70), we calculated that to detect a moderate effect size ($f2 = 0.2$) with 80% power at an alpha level of 0.05 in correlation studies, 191 participants were needed. Anticipating potential dropouts and aiming for robustness in our data analysis, we recruited 210 participants. Eligibility criteria included being a native English speaker, aged 18 to 35, and having no current mental health issues. Participants gave informed consent before their participation and received compensation of $10 for task completion. The Institutional Review Board (IRB) at Pusan National University (no. 2023-49) approved all experimental protocols and methods.

To confirm and generalize our findings on the relation between SWB and self-generated thought contents, we used the independent sample of Korean participants from available data, which had been collected before conducting the main study. This data included a total of 350 participants recruited from the Center for Neuroscience Imaging Research at Sungkyunkwan University, for two separate studies (137 for one study and 213 for another study). These studies were approved by Sungkyunkwan University's IRB (no. 2017-05-001-017 and 2019-06-004-008), with all participants providing written informed consent and receiving compensation for their participation.

Experimental procedure

The main study was structured into two sessions. In the first session, participants were asked to report their level of SWB, which encompasses both cognitive and affective aspects by assessing PA, NA, and LS. Subsequently, they engaged in FAST (5, 6), which was designed to quantitatively analyze the contents and temporal patterns of their self-generated thoughts. After completing the first session, participants were invited to the second session within three days. Out of 210 participants, 192 successfully completed both sessions, with the average time interval between the sessions being 1 day and 3 hours. In the second session, participants were presented with a realistic dilemma in which the value of social relationships and monetary gains conflicted. In particular, participants were required to indicate the income increase that would make them willing to accept a lucrative job offer at the cost of sacrificing their close relationships. Additionally, participants filled out questionnaires measuring materialism and demographic information. FAST was implemented using jsPsych (71), and all experimental procedures were conducted online using their web browsers.

FAST with the main sample

FAST consisted of two parts: a concept generation phase and a concept evaluation phase (6, 42). In the concept generation phase, participants entered a word or short phrase that came to mind in response to a given seed word, and then proceeded to generate subsequent words or phrases in response to the previous concept they had generated every 7 seconds. They were asked to associate a total of 30 consecutive concepts, starting from each seed word. If participants did not provide a word or phrase within the 7-second interval, a warning

appeared, and they were given an extra 4 seconds. This process repeated until they completed generating concepts. After the concept generation phase, participants evaluated the 30 concepts they had generated, in the concept evaluation phase. They evaluated each concept on three dimensions, including emotional valence (i.e., what do you feel when you think about the word?), importance (i.e., how important does the word feel to you?), and other- vs. self-relevance (i.e., how much do you associate the word with yourself versus with others?), on 9-point scales from 1 (very negative; not at all important; completely relevant to self) to 9 (very positive; very important; completely relevant to others). These dimensions are known as core dimensions of self-generated thought contents (36). To provide context for the association between words, the screen displayed two consecutive concepts in sequence, with the second one enlarged to emphasize it as the focus of the trial during both phases (6, 42). The concept generation phase included three blocks starting with three different seed words: a neutral word ("key") and two priming words ("money" and "friend"), resulting in each participant generating a total of 90 concepts. As a result, participants provided 270 ratings in the concept evaluation phase. The order of the seed words was randomized for each participant, while the neutral seed word was fixed first to avoid potential spillover effects.

FAST with the independent sample

Similar to the main study, the independent sample engaged in the web-based FAST, which included two phases for the concept generation and post-survey of the self-generated concepts. During the concept generation, each participant was asked to generate 40 consecutive concepts, starting with one of the seed words ("tear," "family," "mirror," and "abuse"). The order of the seed words was randomized for each participant. Subsequently, participants evaluated the generated concepts based on valence (ranging from -1 for negative to 1 for positive), self-relevance (from 0 for not at all to 1 for very much), and time (from -1 for past, through 0 for present, to 1 for future). As this data was not specifically designed for the main study, the seed words and evaluation dimensions were slightly different from ours (see 6, 42 for the details of this data).

For confirmatory purposes, we only used data from the concept generation phase and SWB measures. Additionally, data from the seed word "abuse" were excluded for the following reasons. First, the valence of the seed word "abuse" (mean = -8.777, SD = 1.774) was markedly lower than those for other seed words including "tear" (mean = -1.411, SD = 3.382), "family" (mean = 6.804, SD = 3.538), and "mirror" (mean = 1.482, SD = 2.590) in a previous survey. Second, the concepts in response to the seed word "abuse" showed the most negative valence (mean = 0.149, SD = 0.237), when compared to those for other seed words ("tear": mean = 0.185, SD = 0.217; "family": mean = 0.245, SD = 0.227; "mirror": mean = 0.220, SD = 0.221). Unlike the original purpose of this independent study that focused on a broader range of emotional experiences (6, 42), we aimed to examine rather neutral or positively tuned concepts of friends and money. Consequently, to avoid any potential biases in strongly negative emotional responses, we excluded the concepts in response to "abuse" from our analysis and analyzed the remaining 120 self-generated concepts per participant. The generated concepts were all in Korean, so we translated them into English to make them

suitable for vectorization.

Dilemma task: choice between social relationships and monetary gains

Participants in the main study were asked to carefully read a realistic dilemma scenario involving a choice between social relationships and monetary gains. The scenario contrasted accepting a lucrative job offer from a top-tier global company at the cost of sacrificing their close relationships or maintaining the relationships with friends and family in their current location. The job offer included a salary increase, regular bonuses, and comprehensive financial benefits, whereas the close relationships provided emotional support, love, and a deep sense of belonging. The job required relocating to a different country, an 8-hour flight away, with uncertain prospects of returning home, thus presenting a conflict between interpersonal relationships and financial opportunity. After reading the scenario, participants were asked to indicate the percentage of salary increase that would make them willing to accept the job offer, with options ranging in 20% intervals from 20% to 200%, or selecting 'unlikely' if no salary increase could justify the move. This question aimed to quantitatively measure the extent to which participants placed value on close relationships over monetary gains. The scenario was previously evaluated in a pilot study (n = 58) based on its plausibility (mean = 69.446, SD = 26.388), psychological conflict between two options (mean = 68.333, SD = 23.666), and balanced representation of the two options (mean = 62.860, SD = 26.430), on a scale from 0 (not at all) to 100 (very much).

Questionnaires

We measured participants' PA and NA using the 12-item Scale of Positive and Negative Experience (SPANE) (33) and LS using the 5-item Satisfaction With Life Scale (SWLS) (32). As a measure of overall happiness, SWB scores were calculated by summing the standardized scores of PA, LS, and NA per participant (i.e., PA + LS – NA) (34, 35). Demographic factors, including age, sex, education, and subjective socioeconomic status (SES) (72), were also measured. Additionally, to control for any potential influence of materialistic attitudes, we measured materialism using the Material Values Scale (MVS) (73).

The independent sample also completed a series of self-reported questionnaires, including the 20-item Positive and Negative Affect Schedule (PANAS) (74) and SWLS (32), along with demographic factors including age, sex, education, and subjective SES (72). We used the PA and NA scores of PANAS for this sample to measure the affective component of SWB.

Similarity to 'money' or 'friend' using Word2vec

To quantify the semantic similarity between the self-generated concepts and the target word (i.e., 'friend' or 'money'), we initially projected each concept onto a 300-dimensional vector using Word2vec (30). These vectors were extracted from pre-trained vectors trained on part of the Google News dataset, with stopwords such as "a," "an," "the," "in," "as," and others removed. For short phrases consisting of multiple words, we calculated the vector for each word individually and then used the average of these vectors. After obtaining a 300-dimensional vector for each word or phrase, we calculated cosine similarity (37), which measures the similarity between two vectors based on the cosine of the angle between them.

The similarity ranges from -1 to 1, where 1 indicates perfect similarity, 0 indicates no similarity, and -1 indicates complete dissimilarity. Specifically, we calculated the cosine similarity between 30 individual words generated for each seed and the target word of 'money' or 'friend,' separately, resulting in six cosine similarities (i.e., cosine similarity to 'friend' or 'money' when the seed was "friend," "money," and "key"; 2 x 3 = 6, for our main sample; when the seed was "tear," "family," and "mirror"; 2 x 3 = 6, for the independent sample). We then averaged these similarities to obtain an overall cosine similarity score for 'friend' and 'money,' which served as our main variables.

We further calculated WMD (38) which quantifies the minimum semantic distance between two documents or sets of words by considering the movement of words from one document to another. Shorter distances indicate higher similarity between the two documents, while longer distances suggest lower similarity. Specifically, we computed the WMD between the 30 words for each seed and 'friend' or 'money,' resulting in six WMDs (i.e., WMD to 'friend' or 'money' when the seed was "key," "money," and "friend"; 2 x 3 = 6, for our main sample; when the seed was "tear," "family," and "mirror"; 2 x 3 = 6, for the independent sample). Subsequently, these WMDs were averaged to derive an overall distance measure for 'friend' and 'money.' Both cosine similarity and WMD are widely utilized across NLP research and are known as robust metrics for assessing semantic similarity that leverage word embeddings (37, 38).

Convergence to 'money' or 'friend' using cosine similarity

To quantify the temporal flows of participants' spontaneous thoughts, we calculated a convergence score based on the trial-by-trial cosine similarity between individual words and 'friend' or 'money' for each seed word. In particular, we derived smoothed similarity functions tailored to each participant, capturing the evolving trend of convergence over time. From these functions, six regression slopes and intercepts were obtained per seed word, where the slopes represented the degree of convergence to 'friend' or 'money' and the intercepts indicated the similarity score of the first trial. Subsequently, we averaged the slope values to obtain an overall measure of convergence to 'friend' or 'money.' The intercepts were included as covariates to control for the effects of baseline similarity for each participant.

Statistical analysis

To explore the relationships between SWB, including PA, NA, and LS, and the self-generated thoughts, we conducted multiple regression analyses. First, we tested a regression model with SWB as a predictor and the FAST variables including cosine similarity to, WMD from, and convergence to 'friend' or 'money,' as well as the evaluation ratings of valence, importance, and other-self relevance. Second, to test the relative effects of PA, NA, and LS, we included PA, NA, and LS in the same model to predict the FAST variables and the evaluation ratings. Third, to examine whether the self-generated thought contents predict choices for social relationships vs. monetary gains, we conducted multiple regression analyses with cosine similarity, WMD, or convergence to 'friend' or 'money' as a predictor and the percentage of salary increase as an outcome variable. Then, to evaluate the predictive performance of the

multiple regression models, we conducted LOOCV and compared the MSEs with those from the regression analyses using the full data set. Additionally, we examined the distribution of cosine similarity to, WMD from, and convergence to 'friend' or 'money', and assessed the variances of these measures using Levene's test for homogeneity of variances. Lastly, we conducted a mediation analysis using the PROCESS macro (75) with 5,000 bootstrap samples to examine whether the self-generated thought contents mediate the association between SWB and the values placed on social relationships vs. monetary gains. For multiple comparison correction for different seed words, we applied the false discovery rate (FDR) criterion proposed by Benjamini and Hochberg (76).

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Data and Code Availability
The data and code for analyses will be shared upon publication at https://osf.io/un3jk/.

Author contributions
I.C. and S.S. initially conceived the study. W.-G.S. elaborated the research questions. W.-G.S., K.W.C, J.A., and S.S. designed the study. J.A. and K.W.C. developed a JavaScript framework designed to support the web-based FAST and laid the groundwork for conducting experiments online. The analytical strategy was mapped out by W.-G.S., J.A., K.W.C., H.L., C.-W.W., and S.S. H.L. took the lead in creating the analytical code, with support from W.-G.S. W.-G.S. collected the data for the main study. C.-W.W. provided the data from the independent sample, which were collected by J.H., E.K., and B.K.L. W.-G.S. analyzed the data and wrote the original manuscript. W.-G.S. and S.S. revised the manuscript. S.S. supervised the study. All authors reviewed and approved the final version of the manuscript for submission.

Competing interests
The authors declare no competing interests.

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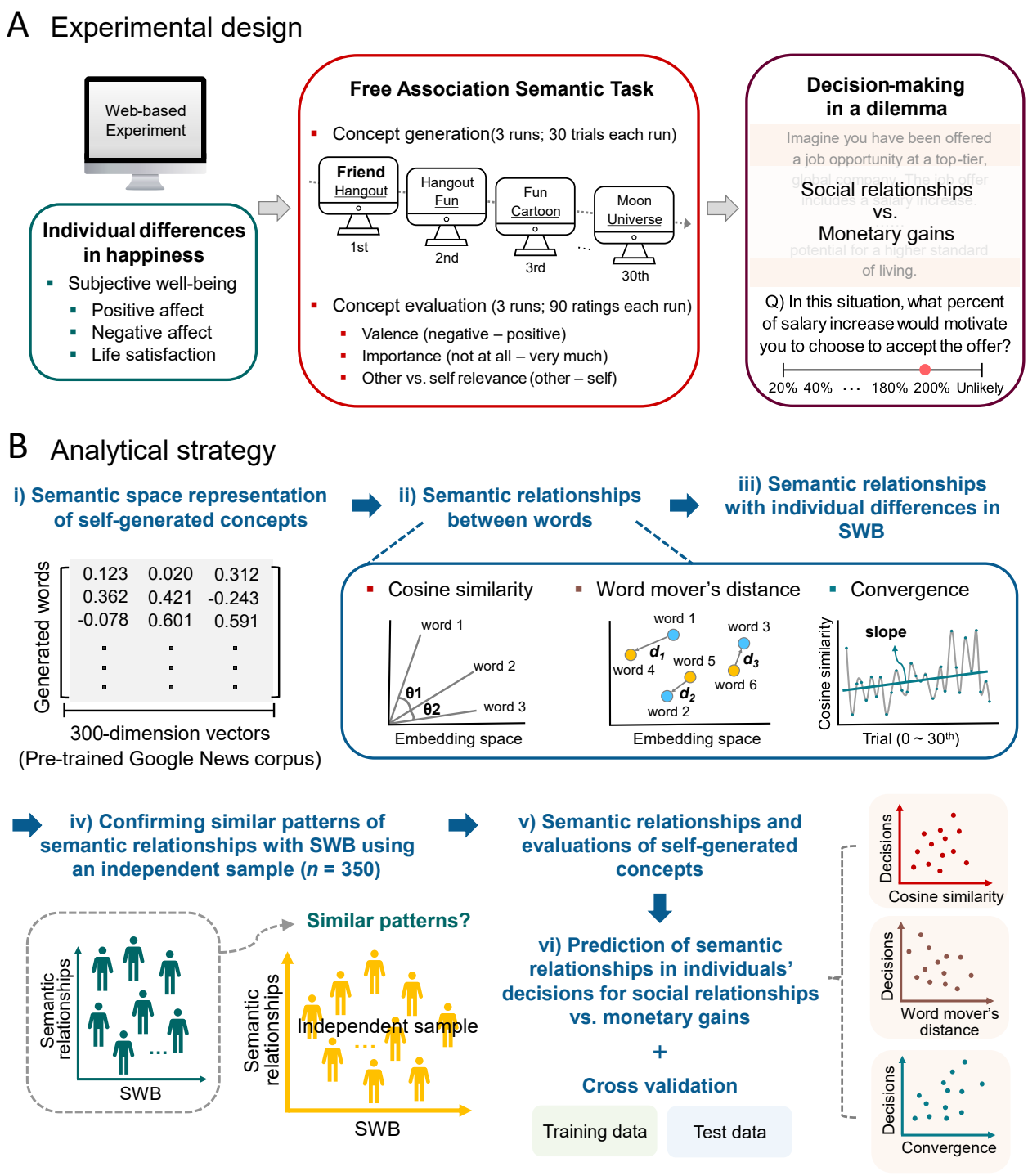

Fig. 1. Overview of experimental design and analytical processes. (A) The study was conducted in two sessions. Initially, participants (n = 210) assessed their levels of SWB, including PA, NA, and LS, and then undertook FAST. FAST involved generating consecutive concepts from given seed words, including "friend," "money," and "key," and evaluating these concepts across three dimensions: valence, importance, and other- vs. self-relevance. After the first session, they were invited to the second session within three days. In this second session, participants (n =192) were presented with a realistic dilemma

in which the values of social relationships and monetary gains conflicted, and were required to indicate the percentage of salary increase that would motivate them to accept the job offer, with options ranging in 20% intervals from 20% to 200%, or selecting 'unlikely' if no salary increase could justify the move (i.e., the extent to which they prioritized one value over the other). (B) To assess semantic relationships between the self-generated concepts and the target concepts (i.e., 'friend' or 'money'), we applied the Word2vec model, pre-trained on the Google News corpus, and represented each concept as a 300-dimensional vector. The semantic similarity was quantified by calculating cosine similarity and WMD between the self-generated concepts and target concepts. These were computed through the cosine of the angle between one word and another, and the minimal semantic distance required to transition from one word set to another, respectively. We also analyzed how participants' concepts increasingly aligned with 'friend' or 'money' across trials (i.e., convergence), using linear regression on individual cosine similarity values. Smoothed similarity functions captured the trend of alignment over time. Then, we confirmed and validated our results using an independent sample (n = 350) for which data on SWB and FAST-related variables were available. Next, we investigated the relationship between SWB and evaluation scores on the self-generated concepts. Lastly, we examined whether the cosine similarity, WMD and convergence scores would predict participants' decisions in the dilemma task. FAST, free association semantic task; NA, negative affect; PA, positive affect; SWB, subjective well-being; LS, life satisfaction; WMD, word mover's distance.

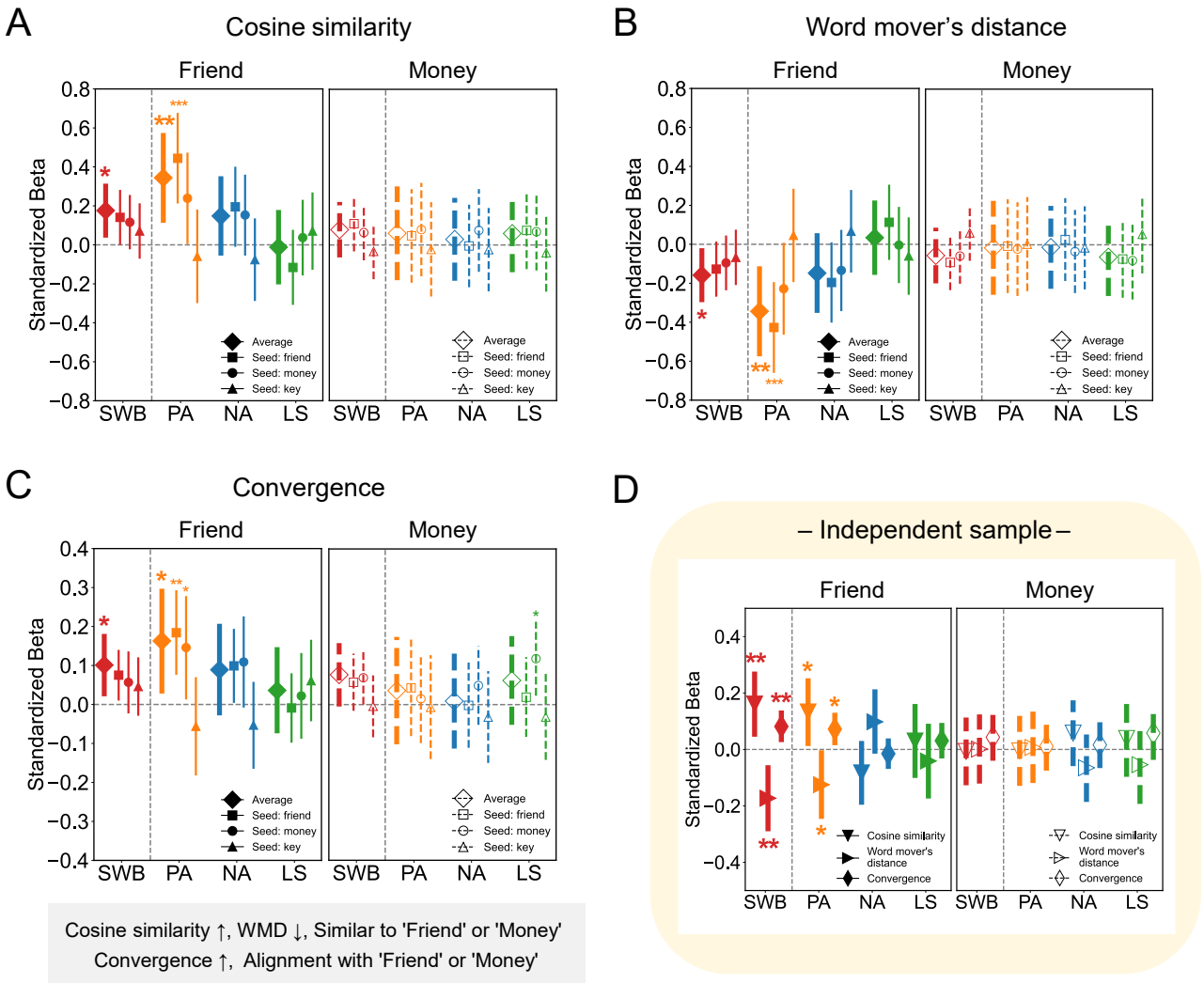

Fig. 2. The relationships between SWB and similarity/convergence to 'friend' or 'money.' Higher cosine similarity and lower WMD or higher convergence indicate greater semantic similarity to or greater alignment with a target concept (i.e., 'friend' or 'money'). The average scores, as our main variables, represent the mean similarity or alignment of the generated concepts to 'friend' or 'money,' regardless of seed words. For exploratory purposes, we also measured cosine similarity, WMD, and convergence for each seed word. Overall, participants with higher SWB, particularly those with greater PA, generated concepts with higher cosine similarity to 'friend' and lower WMD from 'friend,' but not to 'money,' as shown in (A) for cosine similarity and (B) for WMD, respectively. (C) Participants with higher SWB, especially PA, increasingly generated concepts similar to 'friend' over time. (D) We conducted the identical analyses with the independent sample and observed patterns similar to those in our main sample. Specifically, the concepts generated by participants with greater SWB had overall higher cosine similarity to and lower WMD from 'friend,' and they generated concepts similar to 'friend' as the trials progressed. The effect of PA was also evident, as shown in our main sample. The detailed results are presented in Table S3 through S8. LS, life satisfaction; NA, negative affect; PA, positive affect; SWB, subjective well-being; WMD, word mover's distance. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. For different seed words, adjusted P values were applied.

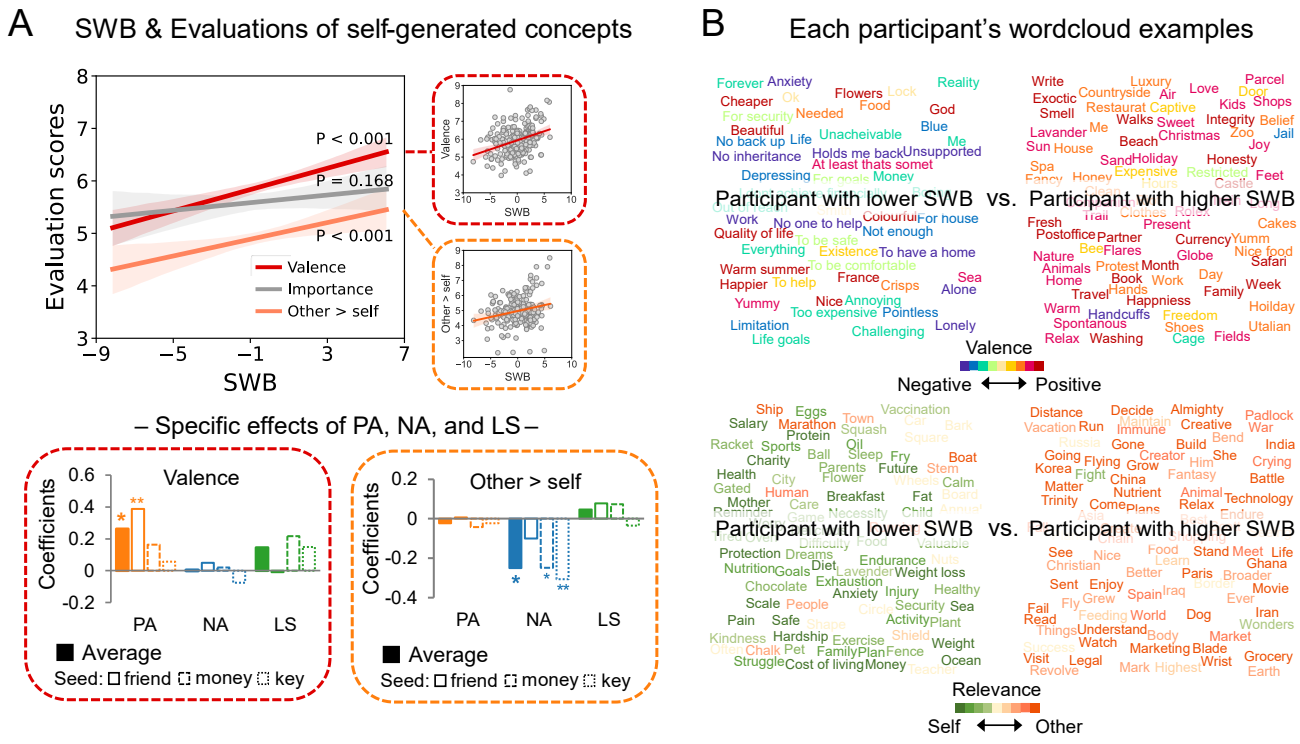

Fig. 3. Evaluations of the self-generated concepts and word cloud examples from four participants. (A) Individuals with higher SWB rated the self-generated concepts more positively and perceived them as more relevant to others than themselves, regardless of the seed words used. When analyzing the specific effects of PA, NA, and LS, greater PA was associated with more positive evaluations of the concepts, while greater NA was associated with greater perceived relevance of the concepts to oneself than to others. The detailed results are presented in Table S9. (B) Word cloud examples from those with higher and lower SWB display the 90 reported concepts, with color coding reflecting the valence scores (above) and the scores of other- vs. self-relevance (below) for each concept. LS, life satisfaction; NA, negative affect; PA, positive affect; SWB, subjective well-being. $*P < 0.05$, $**P < 0.01$. For different seed words, adjusted P values were applied.

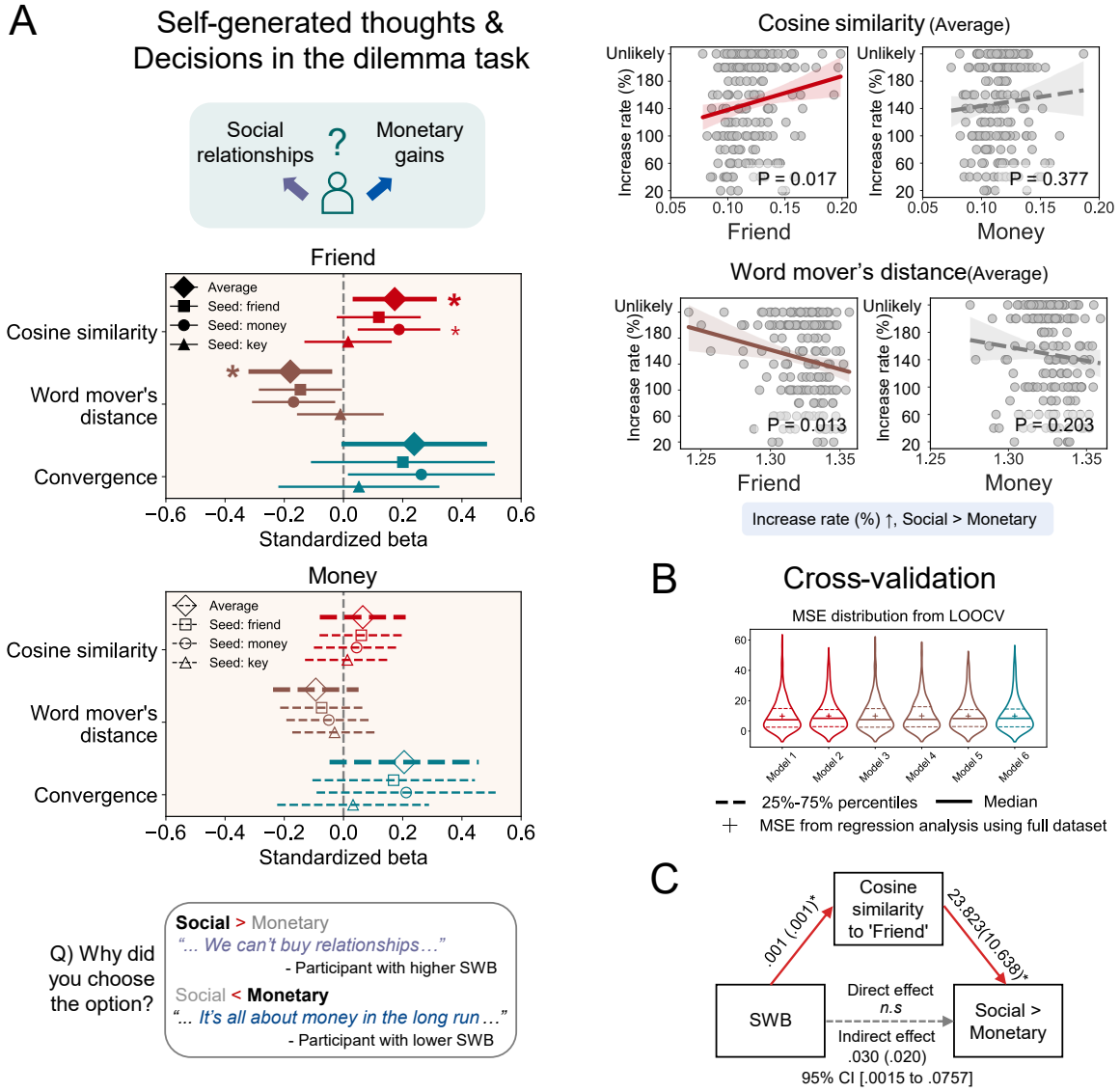

Fig. 4. Similarity and convergence to 'friend' or 'money' and choices between social relationships and monetary gains in the dilemma task. (A) Overall, participants who generated concepts similar to 'friend' in the FAST tended to prioritize social relationships over monetary gains. (B) We compared the MSEs from LOOCV with those from our initial regression analyses using the full dataset to evaluate the predictive performance of our regression models. None of the MSEs from the full dataset significantly deviated from individual MSEs or exceeded one standard deviation from the average MSEs from LOOCV, lending support to the validity of our models. The model number, in sequence, represents the results when cosine similarity (average, seed word "friend," seed word "money") to, WMD (average, seed word "friend," seed word "money") from, and convergence (seed word "money") to 'friend' are entered as predictors. For a more comprehensive analysis, we included the results with uncorrected $p <$ 0.05, as well as those shown in Fig. 4A. The detailed results are presented in Table S10. (C) Participants with higher SWB prioritized social relationships over monetary gains, and this relationship was mediated by the overall greater similarity of the self-generated concepts to 'friend' (See Fig. S1A for the results of the indirect effect of WMD from 'friend'). LOOCV, leave-one-out cross-validation; MSE,

mean squared errors; WMD, word mover's distance. *$P < 0.05$. For different seed words, adjusted P values were applied.