Using Information Processing Strategies to Predict Contagion of Social Media Behavior: A Theoretical Model

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Abstract. This study presents the Social Media Cognitive Processing model, which explains and predicts the depth of processing on social media based on three classic concepts from the offline literature about cognitive processing: self-generation, psychological distance, and self-reference. Together, these three dimensions have tremendous explanatory power in predicting the depth of processing a receiver will have in response to a sender's message. Moreover, the model can be used to explain and predict the direction and degree of information proliferation. This model can be used in a variety of contexts (e.g., isolating influencers to persuade others about the merits of vaccination, to dispel fake news, or to spread political messages). We developed the model in the context of Brexit tweets.

Keywords: Social media · Human behavior · Emotion contagion
Information processing strategies · Behavior transference

1 Introduction

McLuhan [1] argued that "*the medium is the message*" because the medium that people use to communicate shapes communication in profound ways. Not surprisingly, researchers have found that social media as a channel shapes how people attend to and respond to information [2–5]. Despite the ubiquity of social media use, research investigating the association between the use of social networking sites (SNS) and cognitive processing has largely been limited to applied research areas such as mental health outcomes [6–8], marketing [9–11], and education [12, 13]. Nascent research is emerging that takes knowledge from offline environments and applies it to the SNS landscape [14, 15]. However, no studies to date have applied fundamental cognitive concepts to information processing on social media, despite the explanatory potential of these concepts and how they can predict behavior in the SNS environment.

The purpose of our research is to construct a preliminary model that applies cognitive processing to the context of social media. We build upon three classic cognitive concepts in the context of the SNS milieu: the generation effect [16], psychological

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distance [17], and the self-reference effect [18]. This study is focused on the examination of original tweets, retweets, replies, and profile information on the social network platform, Twitter. We situate our findings in a divisive political context that had a potentially significant impact on daily life for a vast number of people—the prospect of the UK leaving the EU, commonly known as Brexit.

2 Cognitive Processing

Our model is informed by foundational research about information processing in an offline context. We propose this model to explain information processing and response behavior in the online context of social networking sites, specifically Twitter. While the model is proposed in the context of Twitter, the concepts are generalizable to any SNS platform (with certain adaptations).

A key concept that applies to our model is *depth of processing*, which refers to the degree to which information that individuals attend to is encoded for current use and storage in long-term memory [19, 20]. Irrelevant or incidental information is likely to be processed at a relatively shallow level, making it less likely to influence behavior and be remembered [21]. Craik and Tulving [21] found that meaningful information, on the other hand, is typically processed at a comparatively deep level. Meaningful information forms links with other related information, becomes integrated into an individual's personal experiences and knowledge base, and is more likely to be remembered and influence behavior (and changes in behavior) than cursory processed information [22].

There are a number of established cognitive mechanisms that predict depth of processing—and consequently behavior, learning, memory, and event recall. For our model, we adopted the three most predominant cognitive mechanisms that predict depth of processing: self-generation, psychological distance and self-reference [23].

Self-generation refers to the degree to which individuals construct material themselves [24–26]. For instance, in the context of Twitter, an original tweet has a higher degree of generation than a reply, and a retweet has the lowest level of generation of response behaviors (such as replies, mentions, and retweets) [21]. In cognition, the generation of new material reflects high depth of processing as an individual is constructing content based on their experiences, knowledge, interests, etc. [24]. Self-generation is also used as a bench march of learning and information proliferation—if an individual has generated content in response to an event or message then they have 'heard' and integrated the content into their existing cognitive framework to generate new material [24, 26].

The second concept that predicts the depth of processing is derived from construal-level theory [17]. According to this theory, individuals process events by developing construals, which are based on psychological distance. *Psychological distance* is the subjective interpretation of how near or far something or someone is in terms of temporal distance (the now), spatial distance (the here), and distance in relatedness (the self) [17]. If an individual deems an event to have low psychological distance (i.e., being close to the self, here, and now), the event is expected to have a profound effect on that individual. From the concept of psychological distance, we incorporated

temporal distance as part of our model. Temporal distance refers to the distance, in time, between an individual's response behavior (e.g., a retweet) and an instigating event (e.g., Brexit).

Degree of *self-reference* is another key concept that predicts the depth of processing; it refers to the degree to which individuals connect the material to themselves [18, 27–29].

In summary, information that is related to the self, created by the self, and close to the self is processed at a deeper level; consequently, it is encoded more deeply in memory than less relevant, distant information. When processing information in working memory, the simultaneous utilization of all three of these cognitive mechanisms (self-generation, psychological distance, and self-reference) yields the deepest level of information processing and long-term memory storage. Information that is processed utilizing only one of these three mechanisms would be processed in a comparatively cursory way. In the next section, we discuss our model that combines these cognitive mechanisms.

3 Social Media Cognitive Processing Model (SMCP Model)

We constructed the social media cognitive processing (SMCP, pronounced "SiMCaP") model to explain and predict cognitive processing in an online context based on social media behaviors (in this case, original tweets, replies, and retweets). The process of communication involves three entities: the sender, the receiver, and the message. Sender and receiver characteristics are pivotal in our model, and they are the lens through which we view content generation and response on Twitter. We use the term *dyad* to refer to the sender of a message (in this case, a tweet) and the person who replies to the message.

In Fig. 1 (left), we show the SMCP conceptual model with its component cognitive processes. Each vertex on the triangle circumscribed by the concentric circles represents the highest degree of the respective cognitive process (namely, directed generation, pairwise similarity, and temporal distance). The shaded area in the center of the triangle is where the highest degree of depth of processing would occur because it reflects the presence of all three mechanisms of cognitive processing.

In Fig. 1 (right), we show the interaction between a sender and receivers of a given message. Each message from a sender has several receivers (R_1, $R_2 \ldots R_n$). The shaded area (in gray) represents one dyad for which the depth of processing is calculated in the SMCP model. The model allows us to compute the depth of processing for each such dyadic interaction between senders and receivers in a given corpus.

We measured three attributes for each dyad, which are coded based on how deeply the receiver processed the sender's information. To measure the degree of self-reference for the receiver in the dyad, we defined the concept of paired similarity by calculating the likeness between a sender and a receiver, both on the level of the message and on the level of the users (explained in detail in Sect. 4.2 below). Support for this concept can also be found in the marketing and rhetorical literature. From the marketing literature, perceived similarity between sender and receiver on social media increases perceptions that the content is trustworthy, credible, and honest [30]. From

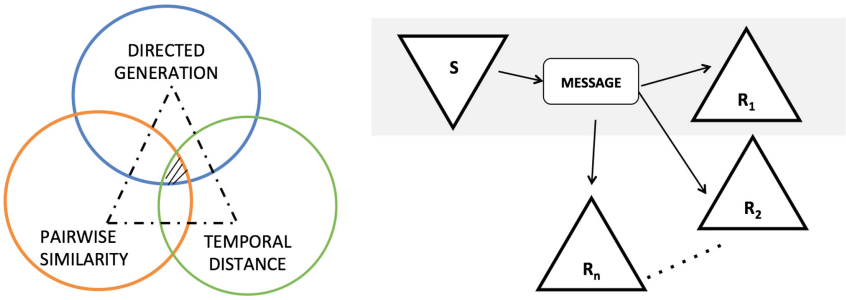

Fig. 1. (Left) SMCP model linking cognitive mechanisms of directed generation. Pairwise similarity and temporal distance. (Right) illustration of dyad relationship between sender (S) and receivers (R_1, R_2…)

the rhetorical literature, the more people identify with one another, the more consubstantial they become [31]. Moreover, a source is more likely to persuade an audience member if the audience member perceives a high level of consubstantiality with the source [31].

The second measure of depth of processing for the receiver in the dyad is called directed generation. As noted previously, it is based on the concept of self-generation (i.e., the extent to which people create their own content). We replaced "self" with "directed" because this new concept measures the degree to which the receiver generates *new* content in response to a sender's tweet. In the context of Twitter, directed generation is the tendency of a receiver to interact with the sender's content (e.g., by retweeting or replying to the sender's message). We posit that receivers who reply more frequently than retweet in response to a sender tend to process the sender's message at a deeper level than other response behaviors, such as liking or retweeting (Sect. 4.3 below).

The third measure of depth of processing in the dyad is psychological distance. We measure psychological distance in terms of the temporal distance (Sect. 4.4) in our model (other measures of psychological distance [17] like geographical distance or social distance will be included in the model as a part of our future work). Temporal distance refers to the distance, in time, between the catalyst for the sender's message (e.g., the UK vote to leave the EU), the sender's content (i.e., a tweet), and the receiver's response behavior (e.g., retweet, reply). As noted previously, temporal distance is reflective of the temporal component of psychological distance.

Having described each measure of the SMCP model, we now explain the model in the context of a specific case study and calculate the associated measures to explain depth of processing for a set of senders and receivers.

4 Method

Figure 2 outlines our overall approach, which we describe in detail in the sections below.

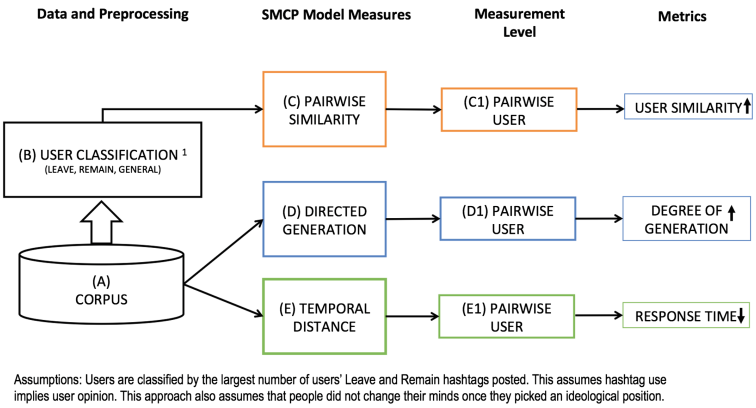

Fig. 2. Outline of overall approach with measurements of each component of the SCMP model and their operationalization.

4.1 Corpus and Preprocessing Steps

We examined a corpus of approximately 2MM tweets regarding the Brexit vote in June 2016 (Step A in Fig. 2). The collected data consisted of a 20% sample of tweets that contained at least one of nine hashtags related to the Brexit event (e.g., #VoteLeave, #Brexit, #StrongerIn) collected via Twitter's GNIP Historical PowerTrack API[1]. The final dataset consisted of 2,171,135 tweets that were shared between June 16th and June 29th, 2016 from 436,474 unique Twitter IDs. From these posts, we examined the set of original tweets (tweets that are not retweets), which consisted 760,964 tweets (35%) in our corpus. We next examined cognitive engagement via the possible actions a user can take on Twitter, such as (1) posting an original tweet; (2) retweeting or sharing an original tweet; (3) replying to an original tweet; (4) mentioning other users in either an original tweet or reply; (5) favoriting an original tweet, retweet or a reply; and (6) quoting another tweet. As noted previously, our model does not account for mentions, favorites, and quotes; however, we aim to include these measures in future work. We note that these actions listed here are specific to the Twitter platform, however, similar actions can be taken on other SNS sites (e.g. Facebook) and the SMCP model can be adapted to those corresponding actions.

As part of the pre-processing steps, we assigned each user to one of three categories (1) Leave (exit the EU); (2) Remain (stay in the EU); or (3) General (ambiguous or undetermined; see Step B in Fig. 2). This classification was made on the basis of the hashtags used in the tweets for each user. If a user's tweets had a majority of hashtags advocating the leave position, the user was assumed to be in the Leave category (and similarly for the Remain category). If a user's tweets contained an equal number of leave and remain hashtags, or if the hashtags were only part of the general hashtags, the user was classified into the General category. Table 1 shows the hashtags and their categorization in our corpus.

[1] http://support.gnip.com/apis/.

Table 1. List of hashtags categorized as one of Leave, Remain or General categories. Hashtags were used to place users in one of these categories.

Leave	Remain	General
#strongerin, #remain, #brexitrejection	#voteleave, #leaveeu, #cleanbrexit	#brexit, #brexitnow, #brexitvote

4.2 Pairwise Similarity

Pairwise similarity (Step C in Fig. 2) is the degree to which the content of the message as well as the sender is similar to the receiver. If the message has content that is highly similar to the preferences of the receiver or if the sender of the message is highly similar to the receiver, the pairwise similarity measure would be high. We posit that this would lead to greater depth of processing, and consequently higher emotion contagion to influence offline behavior. In this article, we measure pairwise similarity as the category to which the sender and receiver belong (i.e. Leave or Remain). If the sender and receiver belong to the same category, then pairwise similarity is high (1), otherwise it similarity would be low (0).

4.3 Directed Generation Measure

The degree of self-generation in the offline context is the degree to which individuals construct original material themselves. In the online context (Fig. 2, Step D), our SMCP model assumes that a reply or a retweet by a receiver is generated material in response to (or *directed* by) a sender; however, replies have a higher degree of generation than do retweets. While retweets are more prolific, retweets represent surface contagion—the information has spread but it may not influence offline attitudes, preferences, or beliefs. Replies, on the other hand, require more effort to generate content than a retweet. We thus formulate directed generation (Fig. 2, Step D1) as the ratio of the total number of actions made by the receiver across all messages sent by the receiver, normalized by the total actions across all receivers and all messages for that sender. Directed generation can thus be characterized as the likelihood of a given receiver to engage with the sender's content, normalized by the general likelihood of which all receivers respond to the sender. We include different actions that a user can take on Twitter and use a five-point discrete scale to weight each action, with Likes being assigned a weight of 1/5, followed by Retweets (2/5), Mentions (3/5), Quotes (4/5) and Replies (5/5). As noted in Fig. 2, the higher the degree of generation, the greater the depth of processing.

4.4 Temporal Distance Measure

The third measure of depth of processing is temporal distance which is measured with respect to the time between the action a receiver takes and the event (the Brexit vote) and also the sender's message. Accordingly, if either the event or the sender's original message is closer in time, the depth of processing will be higher. This is based on the construal-level theory which states that an event closer in time to the self will lead to

lower psychological distance, which in turn leads to greater effects on the depth of processing. We compute temporal distance as the average time taken by the receiver to respond to the messages sent by the sender.

5 Results and Discussion

We illustrate our approach on a subset of senders and receivers from our corpus of over 400 K users. The senders and receivers included the accounts listed in Table 2. We selected 3 senders and 4 receivers based on their classification (Leave vs. Remain), rate of activity on Twitter, and centrality in the retweet network (Fig. 3).

The 'Directed Generation' panel illustrates the tendency of the receiver to generate new content in response to a sender, normalized by the total actions across all receivers and all messages for that sender. Likelihood of the receiver generating new content in response to a sender is depicted via edge weight—thicker edges indicate greater directed generation over other response behaviors less indicative of content generation (i.e. likes). For example, the thickness of the edge between Carl #LeaveEU and LEAVE EU, is greater than the thickness of the edge between *TOM* and 'Vote Leave' indicating that there is a higher degree of depth of processing on the part of Carl #LeaveEU than *TOM*.

The 'Response Time' panel illustrates how quickly a user responds to the message of a sender. Line thickness corresponds with psychological distance such that the thinner the line the less temporal distance there is between the receiver and sender—specifically the receiver responds quickly to the content of the sender.

The SMCP model is a significant contribution because it is the first model that uses classic cognitive concepts to explain and predict responses to social media content. Grounding social media behaviors in established learning and memory theories is critical because it provides a greater understanding of how information disseminated on social media is encoded to potentially influence learning, memory, preferences, attitudes and beliefs.

Similar to other social influence diagrams, SMCP accounts for oppositional positions in mapping the relationship between a sender of a tweet and a receiver of a tweet. However, SMCP goes beyond current diagrams by recording not only the level of effort receivers expend based on their type of social media response (e.g., retweet vs. reply) but also psychological distance to the event and the extent of pairwise similarity between the sender and receiver. Together, these three dimensions have tremendous explanatory power in predicting the depth of processing a particular receiver will have in response to a particular sender's message. Moreover, the model can be used to explain and predict the direction and degree of information proliferation. This model can be used in a variety of contexts (e.g., isolating influencers to persuade others about the merits of vaccination, to dispel fake news, or to spread political messages).

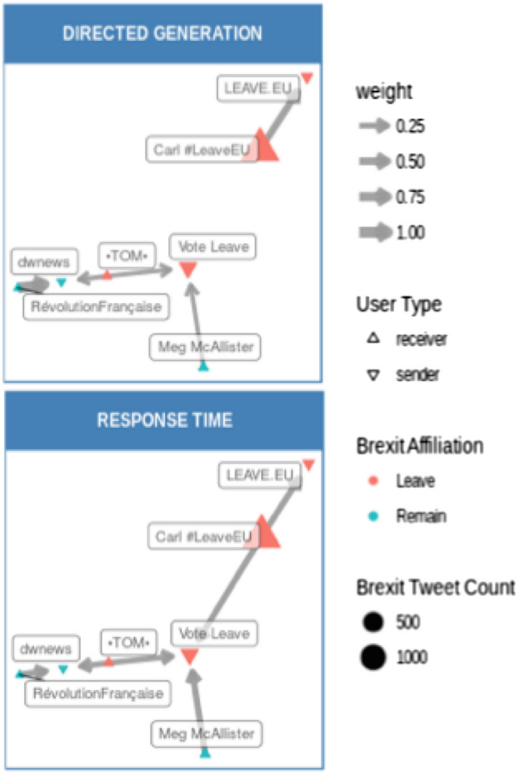

Fig. 3. Network of senders and receivers with edges showing weights of directed generation and response time.

6 Limitations and Future Work

This study represents an initial attempt to identify metrics reflecting pairwise similarity, directed generation and psychological distance on Twitter. Our model relies on several assumptions, which should be considered when interpreting this research. First, we interpreted a user's ideological position based on the hashtags the user used most often (in this case, whether each user posted primarily to the Leave category or to the Remain category). If a user's tweets had a majority of hashtags advocating the leave position, the user was assumed to be in the Leave category (similarly for Remain category). As this is our first attempt, our initial metric of pairwise similarity is simplistic and reflects the context of the sample, future work should identify more nuanced ways to measure similarity such as similarity in profile content or message content between users. We also assumed that a reply or a retweet by a receiver is generated material in response to (or *directed* by) a sender—while replied are generally directed to the sender in response to content from the sender, this is not always the case.

We were also limited to a 20% sample of the GNIP stream for the rule tags we examined. Moreover, the sample did not include favorites, quoted content or mentions

—quoted content and mentions demonstrates a new content generation and would therefore be important to include in future work that refines the directed generation metric. To illustrate the depth of processing between senders and receives in this initial concept paper we also examined only five senders with prolific tweeting and follower numbers to avoid sparsity. Future research should use a larger sample (i.e., 100% sample of GNIP rule tag use) and incorporate favorites and quotes and refine measurement of these constructs in a fuller sample.

As an emerging model, there are many opportunities to build upon this research. Future research should also explore the larger implications of this model, such as using the model to predict emotion contagion. Emotional content tends to be more deeply processed material and linguistic factors could be used to identify emotional content and perhaps create a measure of a receiver's emotional susceptibility to a sender. It will also be important to test this model in other contexts, (i.e., in response to other viral events) as well as incorporate spatial distance into the assessment of psychological distance.

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