

How Far Can the Message Go Through Online Communication: Simulation Outcomes of Information Stickiness

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ABSTRACT

The phenomenon of information stickiness is widely seen by a declined information vitality and is hypothesised with multiple causes, but research on it is scant. Therefore, it is necessary to unmask the myth and concretise the concept. This research adopts an agent-based simulation model incorporating information accumulation, attitudinal proposition, interest, and preference for searching and matching information to determine how identified antecedents affect four defined symptoms of information stickiness in a simulated virtual community. This paper demystifies these symptoms, which are embedded in various personal, relational, and environmental settings. Some aggregate-level outcomes of consumer message-triggered responses emerge as an endogenous outcome of information stickiness. Analysis of data is visualised and quantified for its longitudinal changes in information acquisition, group affiliation, information growth, and the system's vitality.

KEYWORDS

Environmental Disturbance, Halo Effect, Information Dissemination, Learning Threshold, Stickiness, User Preference

1. INTRODUCTION

The technology-mediated community extends social space and social networks from face-to-face to online communication (Treiblmaier and Chong, 2011; Wellman, 1996), where consumers share and exchange content of interests (Hagel, 1999); attach/detach to/from groups (Granitz and Ward, 1996; Ebner *et al.*, 2009); shape delight, engagement, trust, and loyalty toward products; and impose compound influences on others via reviews, comments, and online communication. Notably, the ineffectiveness of information exchange and the declined vitality have become an issue, called information stickiness. Information stickiness is a widely-seen but under-estimated phenomenon, with symptoms including slow information exchange, discontinuous updates, growing information loss, and large information processing costs (Von Hippel, 1998). Though it has been discussed in other contexts hypothetically, it has not been fully explained. Some studies have found that message direction and strength, message relevance to receivers, message travel route, and relative information strength of transferal determine online information's stickiness (Faust and Svensson, 2001; Gupta and Kim, 2004; Meng, 2022). Some organisational studies including ones by multinational corporations (Montazemi

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et al., 2012), have proved that group features (Olmos-Peñuela *et al.*, 2014), the intervention of an opinion leader such as a consultant (Olmos-Peñuela *et al.*, 2014), group learning support (Krishnaveni and Sujatha, 2012), group characteristics such as network structure (Reagans and Mcevily, 2003), individual heterogeneity (Bhagat *et al.*, 2002), and trust (Zhao and Lavin, 2012) can alleviate the symptoms of information stickiness to allow a flowing transmission between destinations. Although these identified factors have been spotted for causing information stickiness from various aspects, a systematic framework is required to integrate all the considerations, which range from personal to interpersonal societal influences.

Inspired by these phenomena, the paper brings up a few questions to consider. First, given that stickiness is almost everywhere, *how to describe and quantify its symptoms in the context of online communication at the aggregate level?* In particular, is it possible to provide generalizable measures of the symptoms embedded in aggregate social relations? Secondly, *what are the antecedents that cause the stickiness, and how do these antecedents lead to the formation and evolution of information stickiness?* To answer the above questions, this paper collects the literature with the antecedents of interpersonal information exchange stickiness, examining the relationship of explanatory factors and the key symptoms via experiments.

Theoretically, the findings show that the personal, interpersonal, and environmental factors of stickiness enrich the theories of information exchange online. *Methodologically*, the approach considers the significance of testing relations within a complex socioeconomic network with multiple players with high internal validity and contributes to the knowledge of information stickiness. This paper claims that to better understand stickiness at an aggregate level, a self-developing approach to link it with the interests and actions of individuals receiving information should be adopted. Next, this research composes and runs a model to report on four aspects of information stickiness: overall sharing speed, information vitality, information growth, and times of disengagement. The results show that information stickiness exists as a phenomenon with different symptoms and is embedded in and traceable back to online customers' micro-level motives and restriction of information exchange and belief-framing.

This research sheds light on the literature for a ubiquitously-existing but underexplained phenomenon, information stickiness, for its formation and evolution. First, the information stickiness of online information exchange is studied extensively for the first time by grounding it into multi-facet discussions when the direct literature to address it so far has been sparse. Second, by collecting and integrating a series of impacting factors to the model of a whole simulation process to model the P2P communication procedure, it adopts a causality-pursuing test in a whole self-reasoning simulation method to represent the mechanism systematically. Though the simulation outcomes need more verification and these research findings are more formative but not conclusive, this paper has tentatively tested how the emerging stickiness symptoms of the four designated aspects may be built on the pathway of some triggering antecedents. Next, the theoretical base of testing is reviewed as follows.

2. LITERATURE REVIEW

2.1 Online Communication

The literature review will address the pertinent components from the perspective of communication's context and procedure respectively. The first grounding of this paper lies in the online information exchange (Treiblmaier and Chong, 2011) which is sophisticatedly embedded in an invisible social network, as a collection of characteristics, e.g., membership, relationship, commitment and reciprocity, shared value and practice, and collectivism (Wellman *et al.*, 1996; Erickson, 1997; Ridings and Gefen, 2004; Olmos-Peñuela *et al.*, 2014). Some studies have proposed conceptual frameworks (Mcmillan and Chavis, 1986; Koh and Kim, 2003; Xiao and Li, 2019) and measures (Koh and Kim, 2003; Blanchard, 2007) of sense of online community highlighting three factors: (1) personal identity or membership featured by a sense of belonging (Mcmillan and Chavis, 1986), (2) relational factor such

as exchange support (Blanchard and Markus, 2002) or influence (McMillan and Chavis, 1986; Koh and Kim, 2003), and (3) group internalization inclusive of integration and fulfilment (McMillan and Chavis, 1986) and immersion (Koh and Kim, 2003).

2.2 Information Stickiness

Another component that underpins the necessity and significance of this paper is the declining capability of information transmission throughout the communication which is a global symptom, a.k.a. stickiness. Information stickiness in peer-to-peer communication context is almost not immutable but can be altered or cushioned in the literature. The primary research on information stickiness defines it as *the incremental expenditure* required to transfer a unit of information to a specified locus in a form useable by a given information seeker, i.e., when the cost is low, information stickiness is low, and when it is high, stickiness is high (Von Hippel, 1994; 1998). Following Von Hippel, some empirical studies have proved that information stickiness is an opposing drive to information sharing. Though most of them are based on organizational settings instead of online community and content communication, which is a typical type of information, has the characteristics of tacit knowledge and is embedded in the context and influencers' features. Therefore, stickiness exists where there is no transparency and is hard to describe and pass on, or where the information exchange has to rely on path dependency or is subject to the match of object and information source (Von Hippel, 1998; Von Hippel and Katz, 2002).

Additional research on customer engagement, value expectation, and interactivity, enriches the stickiness conceptualization. The investigation of stickiness in a customer context shows the influence of customer engagement and customer value creation with company social networks affects the interplay of information and users (Zhang *et al.*, 2017).

Antecedents of Stickiness

Due to inexhaustive explanations existing to explain this phenomenon, this paper searched from the related domains to collect plausible factors from the environment. A critical review of the information transfer theory suggests that according to Szulanski (1996), a message transfer consists of four distinct stages and provides four respective descriptors of stickiness: initiation stickiness, implementation stickiness, ramp-up stickiness, and integration stickiness. This indicates that the problems encountered as the transfer unfolds will vary according to the stage of the transfer.

Looking in a wider scope, we can see that information can be costly to transfer because of the information itself, e.g., the way it is encoded (Nelson, 1982; Rosenberg, 1982; Pavitt, 1987), tacitness of knowledge (Nonaka and Takeuchi, 1995; Hildreth and Kimble, 2002), attributes of information seekers or providers (e.g., a lack of certain tools or a lack of "absorptive capacity") (Pavitt, 1987; Cohen and Levinthal, 1990), the amount or structure of the information that must be transferred (Rosenberg, 1976), specialized personnel (e.g., "technological gatekeepers") (Tushman and Katz, 1980), and specialized organizational structures (e.g., information transfer groups (Katz and Allen, 1985) and learning patterns (Nonaka and Konno, 1998)). Some other supportive factors, such as cultural difference (Szulanski, 1996; Bhagat *et al.*, 2002; Cummings and Teng, 2003), relationship or knowledge gap between source and recipient (Szulanski, 1996; Tyre and Von Hippel, 1997), and exchange support (Wellman, 1996), also have an impact on the extent of stickiness.

Individual Antecedents

Individual Motivation. Earlier studies have addressed the motives for posting reviews (Thorsten Hennig-Thurau *et al.*, 2004) and reading reviews (Goldsmith and Horowitz, 2006). However, the motivation of searching to seek, evaluate, and match information is generally rooted in personal heterogeneity, including experience, affection, commitment, length, and quality of relation (Jalilvand *et al.*, 2011). The range is determined by the complexity of the structure and ties in networks (Wellman, 1996);

for example, dense bounded networks almost always have a small range because a large network becomes unbounded relatively quickly.

Information Preference. The online communication network is embedded in social relationships and can be roughly categorized as either for socialization or truth. “Socialized network” refers to the first type of online connection where the population relatively favours the information adequacy and uses the information attained from the online community for exchange and sustaining social relations, e.g., the credibility of readers and reviewers (Hennig-Thurau and Walsh, 2003). The second type of preference is built on credence. It has been tested of the compounding effects by experiments to investigate the interaction of types of information (Vessey and Galletta, 1991) and message adoption.

Learning Inertia. Heterogeneity in individual characteristics is shown by the uniqueness of the reasoning process, which links information seeking and demand fulfilment. One under-discussed factor is the cognitive difference when exposed to a massive volume of messages. Plausible answers include subjective scepticism (Lee and Youn, 2009; Sher and Lee, 2009), selective acceptance (Park and Kim, 2009), information thresholding (Zhang, 2011), expectancy (Vroom *et al.*, 2005), risk aversion (Casaló *et al.*, 2015), and information anxiety or overload (Olufemi, 2016).

Speciality of Pattern in Information Exchange

Influence-Dominant Vs Attitude-Anchored Knowledge Development. During information acquisition, attitude acts as a moderator to adjust the consequence of message seeking, matching, and internalization. Attitude-combined learning allows the factor of personal attitude as a buffer of new information acquisition and therefore has a more incremental change and knowledge dominant learning focusing on the strength of information and its impact (Packard and Berger, 2017). Psychology research has suggested that confirmation bias or peoples’ tendency to overweigh their prior beliefs or existing hypotheses is ubiquitous (Nickerson, 1998; Narasimhan *et al.*, 2005). With confirmation bias, consumers may be more attentive to information that favours one’s previous belief and ignore incongruent information (Baack *et al.*, 2015) while information that underestimates the target may not easily fit into the prior beliefs.

Halo Effect. The halo effect can lead to “a rater’s failure to discriminate among conceptually distinct and potentially independent attributes” (Thorndike, 1920) and sometimes “flame” or stir up others by using extreme language (Kiesler *et al.*, 1984) to instigate a vitriolic or extreme response. The halo effect theory is used to determine to what extent influencers can persuade consumers to develop credibility and trust as well as shape consumers’ behavioural intentions (Djafarova and Rushworth, 2017).

Environmental Antecedents

Sender-Recipient Relation. Chen and Hung examined the influential factors that impact and benefit community information transfer and suggested that the norm of reciprocity, interpersonal trust, information sharing self-efficacy, and perceived relative advantage were significant in affecting sharing behaviours (Chen and Hung, 2010). Organizational support can hence mobilize information flow (Wellman *et al.*, 1996), through companionship and social support (Sproull and Faraj, 1995), emotional support (Lewis, 2000), group learning support (Krishnaveni and Sujatha, 2012), and social support for information exchange (Wellman, 1996). In addition, some environmental impacts, such as cultural differences (Szulanski, 1996; Bhagat *et al.*, 2002; Cummings and Teng, 2003), are discussed in the literature but are not included in this paper’s framework.

Noise as Disturbance. Information competition has tremendously shortened consumers’ attention span, particularly in online communication. These existing advertising or communications work as the “noise” in the environment, decreasing the buzz time of each focal message and jeopardizing the effectiveness of the message along the timescale.

Information Exchange Facilitated Factor – Promotion. These forms include, in commerce, advertising on social media, sponsoring tweets, promoting favourable messages, using endorsers

for recommendations (Keller and Fay, 2009), appointing brand ambassadors, and referral (Buttle, 1998) to evoke a mass audience to actionable outcomes. Firms, therefore, take initiatives to lead the communication (Godes and Mayzlin, 2009) by promoting the most impressive messages, and this has been empirically studied in terms of effectiveness in various contexts (Kozinets *et al.*, 2010; Lu *et al.*, 2013).

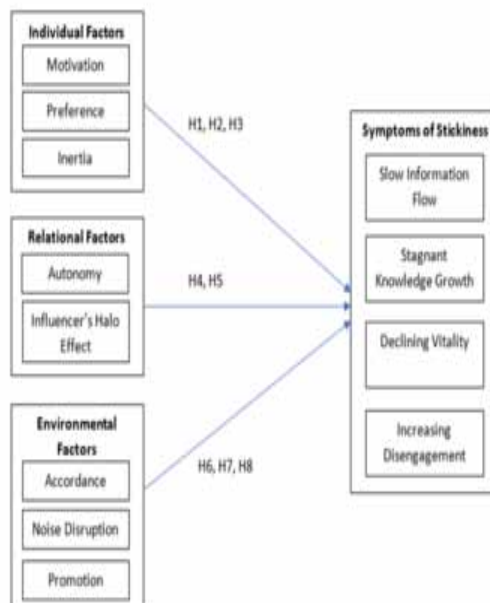
Outcomes And Measures Of Information Stickiness

Information stickiness is discussed and tested in different disciplines, such as macroeconomics (Pfajfar and Santoro, 2010), the stock market (Mankiw and Reis, 2007), and others (Dupor *et al.*, 2010). But if to escape from the context, information stickiness is featured by the aggregate level of measurable symptoms in dimensions for observation: (a) *slow information flow or more a higher reliance only on the local information* (Von Hippel and Katz, 2002), (b) *discontinuous update*, (c) *growing information loss*, and (d) *rising costs of accessing information*. Key factors that influence the difficulty of information transfer are summarised: characteristics of the information transferred (Zander and Kogut, 1995), of the source, of the recipient, and of the context (Arrow, 1969) in which the transfer takes place (Teece, 1977). These factors lead to a variation of frequency to update information by Mankiw and Reis (2007). Also, in terms of information transfer within a firm, the most important knowledge-related impediments are the recipient’s lack of absorptive capacity, causal ambiguity, and the arduousness of the relationship between source and recipient (Szulanski, 1996; Tyre and Von Hippel, 1997).

2.3 Hypotheses

Based on the related literature, this research develops a conceptual model (Figure 1) and some hypotheses to capture the mechanism of information stickiness, mainly capturing three aspects of

Figure 1.



research interest. By operating this simulation model for experimental purposes, first, the research aims to reveal whether there exists stickiness in terms of information exchange flow, online community vitality, information growth rate, and times of disengagement.

To capture the individual characteristics and their impacts, the author develops Hypotheses 1 to 3. Hypothesis 1 to 3 are developed to test the single factor from the three- information motivation (H1), preference (H2), and personal learning capability (H3) may cause a difference in different symptoms of information stickiness.

Hypothesis 1: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H1a), vitality (H1b), volume (H1c), and disengagement (H1d) across search motivations of online community participants.

Hypothesis 2: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H2a), vitality (H2b), volume (H2c), and disengagement (H2d) across information preferences of online community participants.

Hypothesis 3: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H3a), vitality (H3b), volume (H3c), and disengagement (H3d) across learning inertia levels of online community participants.

At the level of the communication processes, Hypotheses 4 and 5 address the impacts of sender-recipient interaction on stickiness:

Hypothesis 4: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H4a), vitality (H4b), volume (H4c), and disengagement (H4d) across different learning patterns of online community participants.

Hypothesis 5: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H5a), vitality (H5b), volume (H5c), and disengagement (H5d) for the extent that online community participants rely on the influencer.

The last three hypotheses are for testing the environmental factors and their influence on stickiness.

Hypothesis 6: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H6a), vitality (H6b), volume (H6c), and disengagement (H6d) across rewarding strengths in accordance with the online community.

Hypothesis 7: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H7a), vitality (H7b), volume (H7c), and disengagement (H7d) across environmental noise levels in the online community.

Hypothesis 8: Aggregately, information stickiness exists in the form of a declining information exchange tendency and displays a different evolution pattern in terms of information flow (H8a), vitality (H8b), volume (H8c), and disengagement (H8d) across promotional levels imposed on online community participants.

3. STUDY OVERVIEW

3.1 Research Design

This research engages a programming technique via Haskell language to compose a simulation model to model the peer-to-peer communication and rule out the causality by setting different bands of value in parameters. In the simulated communication system, each agent performs its' role to fulfil the demand of information seeking and simultaneously plays as the information source to influence others through connection and persuasion, for example in the research of Xiao and Li (2019) and Meng (2022). A series of parameters are set, including information preference, information valence, attitudinal direction, virtual presence in connection network, and earned social identity from peer recognition through information exchange. These experiment methods (Charness *et al.*, 2012) can be substantially supplemented with simulation for theory development and testing in aggregated behavioural patterns. This has also achieved vast applications in virtual community research (Goldenberg *et al.*, 2001; Smith, 2010; Rand and Rust, 2011; Libai *et al.*, 2013) due to its strength in isolating or matching controlled variables to realize a full randomization design (Harrison *et al.*, 2004). This research adopts Haskell programming for user-to-user information transmission simulation. This research assumes message transmission to be interpersonal communication, adopts a sender-recipient interaction rule, and focuses on the motives and identity of individuals as the results. Following the method of stochastic cellular automata (Goldenberg *et al.*, 2001) to understand the aggregate consequences of opinion dissemination based on local interactions between agents according to the ruleset, this research adopts a simulation method to experiment and fill the knowledge gap and further the scope of future research. As an important form, computational simulation can assemble the factors with random assignments of initial values and interactive gains of the agents to avoid bias in the self-reasoning process of the exogenous variables, and to achieve the research objectives by customizing analytics for the report.

3.2 Parameters And Interaction Rule

To control the bias brought by the initial setting of the model, this paper models randomized demands of information need. Therefore, other variables are randomly assigned to control the variation and the corresponding impact on the observational results. By the following framework of Baek *et al.*, this study assembles the valence and volume as the fundamental design for simulation (Pavlou and Dimoka, 2006; Baek *et al.*, 2012). Individuals interact, search, match, exchange, and share messages with their demands within the online community (Meng, 2022). Notably, an earlier study has identified two distinct types of information preference (Bieber *et al.*, 2002), one focusing on the informative utility of information acquisition and the other on the interactive utility of interpersonal communication via sharing.

To monitor if the speed of information flow varies, the outcome reports the *growth rate of information exchange times* of the whole group; for the system-wide information loss, this paper uses the *change rate of the propensity* of imposing influence to represent the inclination of updating. To show if the system acquires a higher level of cumulative knowledge after information exchange, the *information growth ratio* is reported (reverse to the sticky symptom of information loss), and to show the varied centrality of influencers in communication, *the ratio of connected but not exchanged contacts* is reported to all contacts as the indicator of information centrality.

3.3 Manipulation

Table 1 shows the parameter setting of the examination and control groups in each study.

Table 1. Parameter Summary of Experiment Groups

Study	Objective	Treatment	Manipulated Coefficient of Agent	Controlled conditions
1	Motivation of search	Small search scope	A small agent's search radius $\lambda \sim (0, 10)$	Random preference $\alpha \sim (0, 1)$ Inertia λ randomly \sim medium range Attitude-combined learning pattern Medium halo ratio Medium reward coefficient level μ Medium decay coefficient β Medium promotion coefficient
		Universal search	A wide agent's search radius $\lambda \sim (0, 100)$	
2	Information preference	Socialization	Relative significance on information adequacy when searching the source	Medium search scope Inertia λ randomly \sim medium range Attitude-combined learning pattern Medium halo ratio Medium reward coefficient level μ Medium decay coefficient β Medium promotion coefficient
		Credence	Relative significance on information credibility when searching the source	
3	Inertia	No update threshold	No learning cost of agent's update	Medium search scope Random preference $\alpha \sim (0, 1)$ Attitude-combined learning pattern Medium halo ratio Medium reward coefficient level μ Medium decay coefficient β Medium promotion coefficient
		With update threshold	With learning cost of agent's update (only information strong enough to break through will be passed on)	
4	Learning	Self-reasoning by influencer	Update agent's information acquisition based on the source's knowledge level	Medium search scope Random preference $\alpha \sim (0, 1)$ Inertia λ randomly \sim medium-range Medium halo ratio Medium reward coefficient level μ Medium decay coefficient β Medium promotion coefficient
		Attitude combined reasoning	Update agent's information acquisition based on whether the source fits the agent's earlier attitude	
5	Influencer's impact	No halo effect	No amplifying information when exchanging	Medium search scope Random preference $\alpha \sim (0, 1)$ Inertia λ randomly \sim medium-range Attitude-combined learning pattern Medium reward coefficient level μ Medium decay coefficient β Medium promotion coefficient
		Large halo effect	Amplifying information from selected influencers when exchanging	
6	Reward	Low reward on the agreement	Low psychological reward for sender-recipient agreement	Medium search scope Random preference $\alpha \sim (0, 1)$ Inertia λ randomly \sim medium-range Attitude-combined learning pattern Medium halo ratio Medium decay coefficient β Medium promotion coefficient
		High reward on the agreement	High psychological reward for sender-recipient agreement	
7	Noise	Low noise	Big information remaining coefficient attached to information exchange	Medium search scope Random preference $\alpha \sim (0, 1)$ Inertia λ randomly \sim medium-range Attitude-combined learning pattern Medium halo ratio Medium reward coefficient level μ Medium promotion coefficient
		High noise	Small information remaining coefficient attached to information exchange	
8	Promotion	Light promotion	Small intensity coefficient applied to the agent's information strength	Medium search scope Random preference $\alpha \sim (0, 1)$ Inertia λ randomly \sim medium-range Attitude-combined learning pattern Medium halo ratio Medium reward coefficient level μ Medium decay coefficient β
		Heavy promotion	Big intensity coefficient applied to the agent's information strength	

4. ANALYTICAL RESULTS

4.1 Section 1: Test Of The Personal Characteristics On The Formation Of Stickiness

The first section aims to cast a light on individual motives and actions of information search and exchange. The personal factors include cognitive restriction (motivation), preference, and inertia (as learning costs), as shown in Table 1. The paper shows the longitudinal evolution of the four outputs with the regressed lines added to indicate the overall trend of change. The downward trend of lines in the three indicators, i.e., *the change of exchange information flow, communication vitality, and*

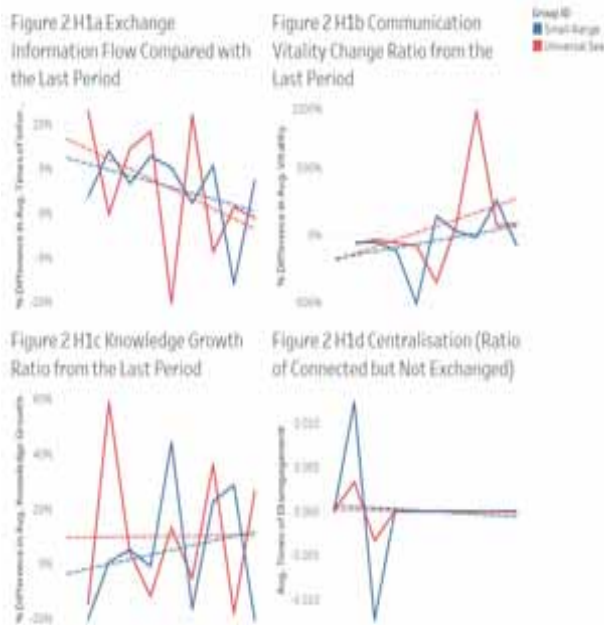
information growth from the last period, imply the existence of information stickiness. While the last indicator, *times of disengagement over time*, presents the difference in the number of connections and exchanges, suggesting the centrality of the communication and therefore the existence of stickiness if with an ascending line.

Factor 1 – Search Motivation

For the macro-level stickiness, the first study designs two conditions that are assigned to individuals when searching around to build a connection for exchange. The conditions are associated with a parameter, suggesting different bubble sizes for information search. This parameter is manipulated, i.e., small-range search and universal search.

Figure 2 H1a to H1d show the following findings. First, information flows appear to descend in two conditions. However, with the increasing stickiness evidenced by slower information flow, the propensity (Figure 2 H1b) and prosperity (Figure 2 H1c) of knowledge creation appear to grow aggregately over time but with a decreasing trend of disengagement (Figure 2 H1d).

Figure 2.



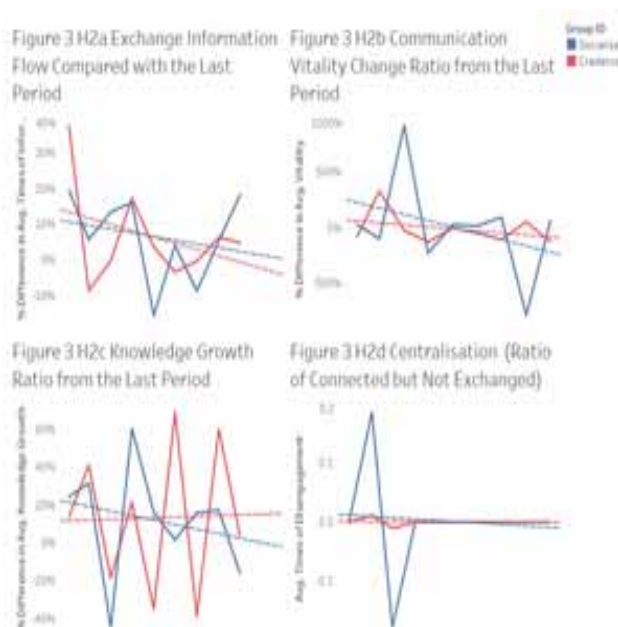
Secondly, the growth of the searching radius increases the complexity of problem-solving and increases stickiness. An earlier study found that as the number of network members increases arithmetically, the number of connections required to sustain full connectivity increases geometrically (Wellman, 1996). In this study, for example, highly-motivated far-ranging searches suffer a higher drop rate in exchange flow (Figure 2H1a). However, they seem to be less sticky, evidenced by the steeply growing trend of communication vitality (Figure 2 H1b). As active as this scenario is, such a universal search fails to grow the information on the offer of the whole system, contrasting the low motivation group (Figure 2 H1c).

Thirdly, Figure 2 H1d shows that the low-motivation group encounters a bigger variation in the average number of disengagement times than for individuals from higher motivation groups. The higher motivation in search interest has an almost unchanged mean in disengagement times. The nearby search behaviour appears to decrease slightly more effectively than the times of disengagement when compared with higher motivation ones.

Factor 2 – Information Preference

The second study focuses on how an individual’s different criteria of evaluating and passing on a message have impacted the information stickiness. In this study, two conditions are composed to be evaluated against each other with a relative coefficient as each customer’s cognitive importance of socialized information and credible information. The results are seen in Figure 3 H2a to H2d, reporting the overall inclined marginal percentage of exchange times (Figure 3 H2a), reduced inclination of information spillover (Figure 3 H2b), stagnant growth of information exchange (Figure 3 H2c), and almost unchanged times of disengagement (Figure 3 H2d). In particular, this study draws attention to the conditional difference of stickiness in existence. In an environment where the audience favours socialized communication and appreciates adequacy over credence of the message, the exchange flow of information declines less dramatically but suffers a steeper decrease of vitality and growth rate.

Figure 3.



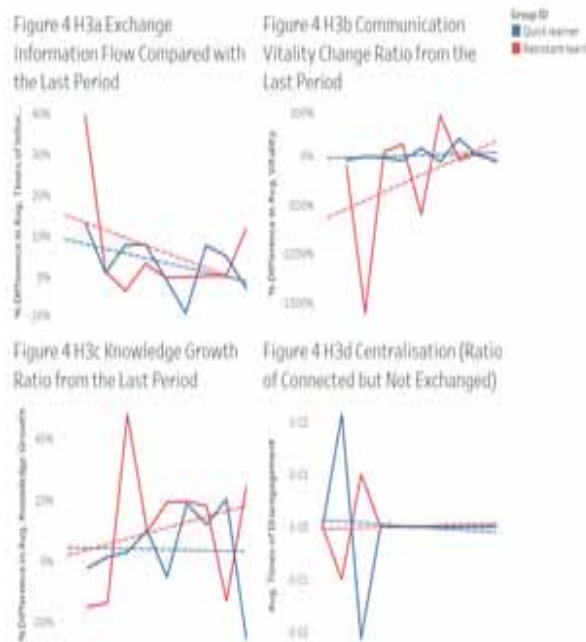
The findings show how the audience’s information preference may adjust the information stickiness. Credence-favoured customers receive a steeper decline in exchange flow change than in the last period (Figure 3 H2a). In contrast, socialized customers witness a quicker decrease in communication vitality (Figure 3 H2b) and information growth (Figure 3, H2c). Both groups demonstrate a roughly similar trend in the change of disengagement percentage. Socialized customers are more likely to reduce the gap of disengagement based on the mutual connection (Figure 3 H2d).

Factor 3 – Inertia/Threshold

The third study addresses the research question of how individual inertia alters the expected indicators. In this study, a parameter of the information exchange threshold is manipulated at two levels (low and high) indicating the quicker learners and resistant learners. Only the biggest information difference between sender and recipient can trigger a connection and exchange for resistant learners, while the low threshold can enable the customers to be quick learners.

The findings are presented with both the charts and regressed lines. Resistant learners (red) have a more dramatic drop in exchange flow based on the past (Figure 4 H3a) but a quicker climb-up in the general communication propensity (Figure 4 H3b) and knowledge increase (Figure 4 H3c) over time.

Figure 4.



All the learner groups become centralized efficiently (Figure 4, H3d). The higher learning inertia the customers have, the more disengagement times they own. Therefore, it can be proposed that the level of learning inertia has a positive relationship with the stickiness in terms of disengagement times.

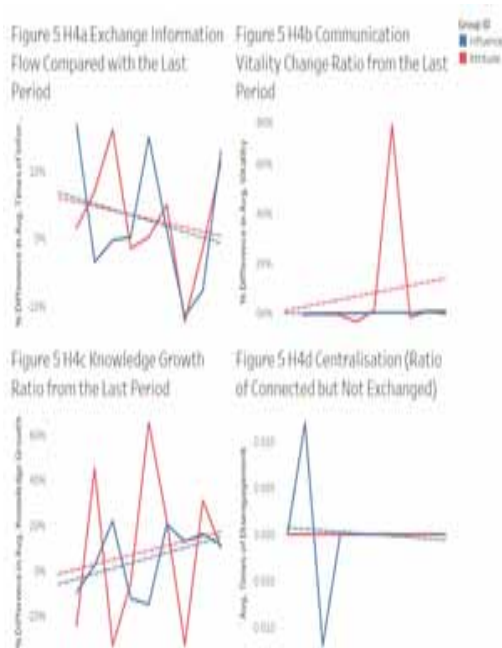
4.2 Section 2: Test Of The Relational Characteristics On The Formation Of Stickiness

Messages are received and evaluated against an individual’s belief and demonstrate different influences via different reasoning paths. This section aims to reveal the mechanism of opinion leaders’ impact on the mass public, i.e., how the deliberate information is evaluated and adopted in contrast to one’s prior attitude and how influencers have taken their roles in influencing the customers and fans. Specifically, two variables are selected for testing the influencing procedure between sources and recipients, i.e., the reference to prior attitude and their halo effect on recipients.

Factor 4 – Influencer’s Impact

The fourth study addresses the research question of how different learning patterns may change the overall communication performance. Two kinds of learning are used to model the influencers’ impact on self-adjustment of knowledge gains with or without considering the pre-held attitudinal position regarding the subject in focus. One condition shows the utter information-based reasoning (shown in blue colour in Figure 5 H4a to H4d), which means that individuals fully exchange and accept information based on the strength of influence (such as expertise and profession of the source) without referring to their earlier belief. And the red curves in Figure 5 H4a to H4d are the status when an individual’s past attitudes are considered to impose incremental changes to let people enrich only the knowledge that is anchored around their previous attitude.

Figure 5.



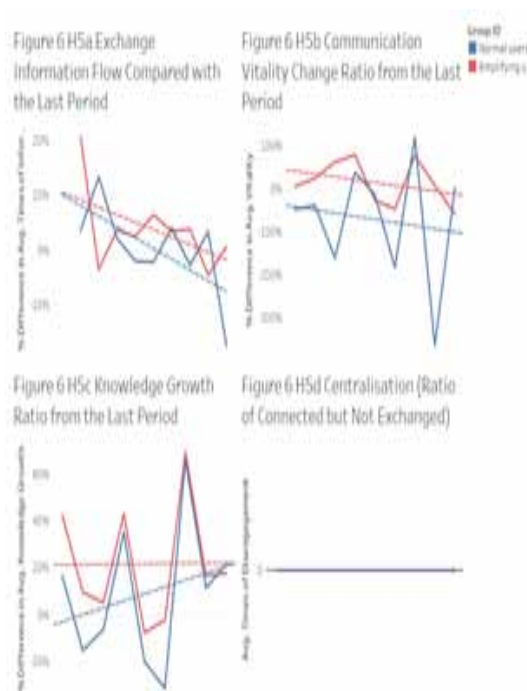
It is shown that when customers in an online community shift their information adoption based on their attitude, the whole online communication owns a higher increase rate of opinion sharing propensity over time than when the audience is purely reliant on the message’s strength. In other words, the attitude-combined reasoning of the commercial information can alleviate stickiness by buffering the decline of vitality (Figure 5 H4b).

Factor 5 – Influencer’s Halo effect

The fifth study focuses on the amplifying effect of adopting information from selected senders, i.e., those highly-regarded influential sources such as a celebrity. A parameter is created to be attached to the received information utility from the source and to be passed on for the next exchange. This parameter is manipulated with two levels: the value 1 representing no halo effect (blue) and 1.5 for large halo effect (red).

In general, stickiness exists in the form of exchange flow (Figure 6 H5a) and communication vitality (Figure 6 H5b), evidenced by a declining regressed line. To look at the between-group difference, the amplifying group receives a less sticky exchange flow rate, but both groups witness a drop of information update ratio (in Figure 6 H5a). The two groups demonstrate almost the same rate of decline in communication vitality change (Figure 6 H5b) and centralization (Figure 6 H5d). However, a larger halo effect barely contributes to the whole online community's information growth compared with the normal audience.

Figure 6.



4.3 Section 3: Test Of The Environmental Factors On The Formation Of Stickiness

Some contextual variables, such as psychological rewards, disturbance from competing news, and advertising reinforcement, change the dynamics of information's flow in its designated audience. Section 3 is designed and operated to show how contextual factors change the evolution of information stickiness. In this section, three factors are assembled for testing.

Factor 6 – Rewarding for Accordance

Study 6 takes the group reward of reaching an agreement as to the treatment and manipulates for low and high levels by recipient utility after the exchange.

Like in other studies, the exchange rate declines in both conditions as a typical symptom of stickiness (Figure 7 H6a). Generally, rewarding has displayed a significant role in alleviating stickiness by creating the lowest drop or the quickest growth of exchange update speed, vitality, and information growth (Figure 7 H6a to H6c) as well as the fastest bridging of the disengagement gap (Figure 7 H6d).

In particular, it is shown in Figure 7 H6a that the extent of rewarding has a negative relation with information stickiness by exchange flow's decreasing rate. High rewarding is an effective group

Figure 7.

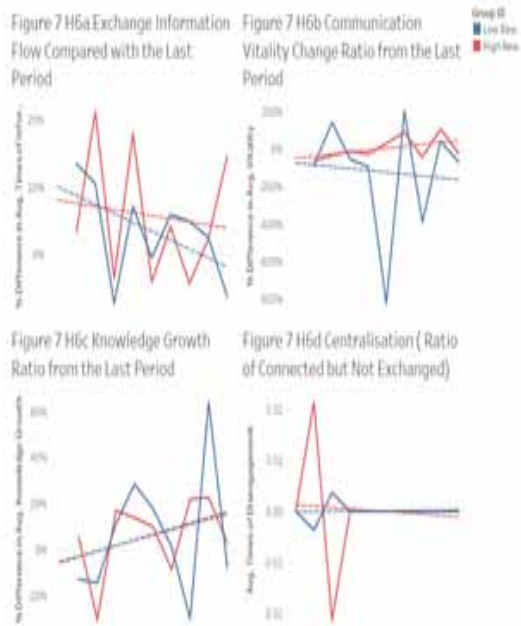
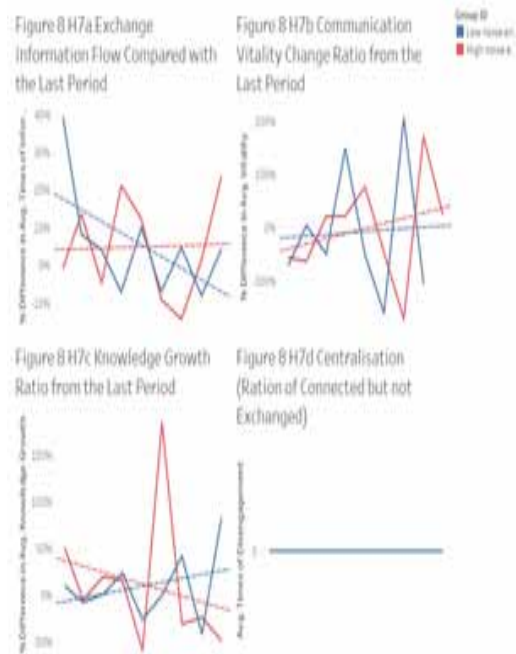


Figure 8.



learning approach, encouraging the increase of vitality (Figure 7 H6b) and information growth (Figure 7 H6c). In Figure 7 H6d, highly rewarded customers also underpin a shortened gap of disengagement between connection and exchange times over time (in red).

Factor 7 – Environmental Noise

The next factor is the environmental disturbance, with typical examples including all the other buzzing news that attracts customers’ interest and shortens the span of attention. The seventh study presents an experiment regarding the impact of environmental noise from other messages that compete for the audience’s attention. The existence of a high volume of messages as a disturbance (red) rescues the drop of exchange flow (Figure 8 H7a), but at the same time, it declines the vitality (Figure 8 H7b) and information growth in the community (Figure 7 H7c). Also, the noise in the environment has no significant impact on the occurrence of disengagement in communication by percentage (Figure 8 H7d).

Factor 8 – Promotion

The last study answers the research question, i.e., whether a global promotion of the contents (such as more investment in advertisements to buzz the topic) on the network can benefit communication by alleviating the stickiness in information sharing. In this study, a parameter is created and attached to the global network to make content more impressive and memorable. Based on this notion, the promotion coefficient is manipulated using two values: 1.2 for light promotion and 1.5 for heavy promotion.

It’s found that both conditions produce a declining rate of information update and a quickly centralized procedure when the decreasing number of sources takes the role of influencing others by an exchange. To summarise from the graph, the author draws an important conclusion that promotion can decrease the information stickiness by increasing exchange flow (Figure 9 H8a) at the cost of decreased marginal communication vitality (Figure 9 H8b) and system-wide information growth (Figure 9 H8c).

Figure 9.

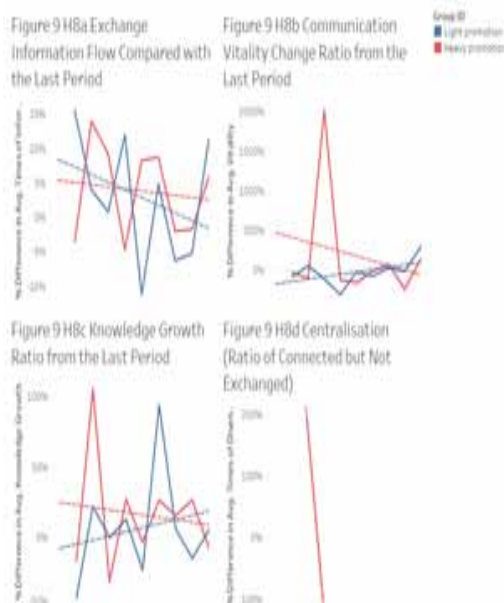


Table 2. Review of Hypotheses Tests

		Indicators of Aggregate Stickiness			
		Information exchange (declining rate in all situations)	Communication vitality (varied change rate)	Information growth (varied change rate)	Ineffective engagement
Solicited individual factors	Motivation for searching and circulating information	H1a – a strong search motivation suffers a significantly declining exchange rate than low motivation groups	H1b – increases in both conditions, a higher motivation unexpectedly pushes the communication vitality up	H1c – increases in both conditions, low motivation gives the online community a higher information growth compared with higher motivation	H1d – higher motivation gives a less dramatic drop than low motivation
	Preference for accepting information (credence vs socialization)	H2a – when the population is seeking credence when adopting information, exchange flow drops at a steep rate	H2b – drops in marginal rate in both conditions, but socialized communication receives a steeper drop rate than credence favoured audience in communication vitality	H2c – drops in marginal rate in both conditions, but the credence-seeking population reverses the declining trend of information growth rate and achieves an ascending trend	H2d –socialization preference has a faster drop rate than the credence-seeking preference in times of disengagement, which means in a more active and vibrant population, more information exchanges are built
	Threshold of learning	H3a – quicker learners drop their exchange rate quicker than resistant learners	H3b – increases in both conditions, the resistant learners have a higher climbing rate	H3c – increases in both conditions, information growth unexpectedly has the fastest growth among resistant learners	H3d – resistant learners have a slight increase in disengagement times, contrasting fast learners
Interaction process	Reasoning process with new information	H4a – attitude-combined learning pattern has a relatively modest drop rate compared to the information-dominant influence	H4b – increases in both conditions, attitude combined learning has a dramatically growing trend (less sticky)	H4c – increases in both conditions, attitude-combined learning has a sharper growth rate in new knowledge gains	H4d – influencers’ impact characterizes the learning with an obvious drop in disengagement times (the attitude-combined learning is stickier in disengagement)
	Exaggeration of influencer’s impact	H5a – large halo effect has a larger declining rate in exchange flow over time	H5b – drops in both conditions, almost the same descending speed but the amplifying audience has a higher communication vitality	H5c – halo effect is stickier evidenced and less contributory to the growth of new information acquisition	H5d – not a significant difference
Group level factors	Infrastructure and rewarding	H6a – larger rewards for agreement cause a less sticky outcome in terms of the declining exchange flow	H6b – a high reward group has a higher vitality in communication than the low reward group	H6c – with a growing trend in both conditions, but not a significant difference	H6d – the high reward group also has a declining disengagement trend
	Noise	H7a – in the disturbing environment, the exchange flow declines slower than that in the low noise environment (less sticky)	H7b – with a growing trend in both conditions, the less noisy environment cultivates a higher vitality of communication	H7c – in a noisier environment information growth is more stagnant than in a peaceful environment	H7d- remained unchanged, no significant difference
	Promotion	H8a – the promotion activity has supplemented the drop of exchange flow to some extent	H8b –a stronger promotion can barely sustain a higher communication vitality	H8c – a stronger promotion cannot warrant a higher rate of information acquisition (stickier), it is more likely to witness information growth in a light promotion group	H8d – promotion turns out to help reduce the times of disengagement, evidenced by the declining ineffective connecting times

5. CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

As some simulation-based research has indicated, the structural changes in social relations may be embedded in micro-behaviours, for example, online communications (Meng, 2022), where significant evolutions are reasoned out from the bottom-up logic to explain the evolution of observation. As an accumulated phenomenon, the stickiness can be witnessed microscopically by the amount of information exchange and times of engagement in information exchange among individuals and aggregately by the exchange times, growing spill-over, and the times of disengagement in information circulation. In addition, the discoveries also supplement the literature on the formation and evolution of between-user interaction by embedding the informative and social consequences in consumer actions (Goldenberg *et al.*, 2001). To summarise the testing of our hypotheses, Table 2 reviews our findings.

First, the information stickiness of online information exchange is a multi-facet concept with static, dynamic, longitudinal, and distributive features. Though the four indicators adopted in this study are more diagnostic than conclusive and therefore inexhaustive to the profound nature of stickiness, the speed of flow, vitality, information acquisition, and centrality are found to be able to depict the kinetic nature of stickiness to some extent. Information flows in all conditions demonstrate a declining trend, which proves that information stickiness was developed out of micro message exchanges. While behind the variation of flow decline, a few other indicators are depicting different aspects of this concept. Under some circumstances, these indicators appear to alter in the opposite direction to the flow change.

Secondly, though users are sometimes resistant to a new message, the vitality of communication can boost when individuals are motivated, credence-seeking, sticky to prior belief, and encouraged to remain in agreement with their surroundings with a reasonable level of external promotion. To target an increase of information level of these users, it is suggested that a small range search will be more effective than doing a global search. Nevertheless, using strong influencers such as opinion leaders or experts will guide those who are strongly resistant to bear the message.

Our research has limitations that offer room for future research. Due to a simplification of the manipulated situations in experiments, the study bears a restricted external validity though being able to single out the relation in each isolated situation. Secondly, this modelling approach typifies but also simplifies the profound social-psychological motivations for consumers' message-triggered responses like affiliation vs detachment and advocacy vs backlash. Thirdly, in the future, more interactions of the observed factors are expected by following this study's framework. As a ground-breaking study to pinpoint the issue with significance, this research bears the huge potential to be solidified and supplemented with empirical data collected across other methods.

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