Use of dynamic systems methods to characterize dyadic interactions in smoking cessation behavioural support sessions: a feasibility study

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Abstract

Background: Understanding how behaviour change techniques (BCTs) operate in practice requires a method for characterizing the reciprocal, dynamic and real-time nature of behavioural support interactions between practitioners and clients. State-space grids (SSGs) are an observational, dynamic systems methodology used to map the trajectory of dyadic interactions in real time. By mapping the flow of events in terms of practitioner and client actions, SSGs are potentially well-suited to characterize behavioural support sessions.

Purpose: To develop reliable methods and examine the feasibility of using the SSG methodology for characterizing practitioners' delivery of and clients' response to BCTs in smoking cessation behavioural support sessions.

Methods: Smoking cessation behavioural support sessions were video-recorded and transcribed verbatim (n=6 recordings; 2916 statements). All speech was coded independently by two researchers for content and duration using published frameworks for specifying practitioner-delivered and client-received BCTs in smoking cessation interactions. Inter-rater reliability was assessed. Indices of practitioner-client interaction dynamics were derived: 1) reciprocity (i.e. attractor states, content congruence, conditional pairing) and 2) temporal patterning (i.e. variability, inter-grid distance, combinatory micro-patterning, sessional macro-patterning). The extent to which indices can describe differences between sessions involving different practitioners and clients was examined.

Results: Inter-rater reliability was moderate at 72% agreement. Indices of reciprocity and temporal patterning characterized differences between sessions involving different practitioners and clients.

Conclusions: State space grids provide a method for characterizing the complexity and variability of practitioner-delivered and client-received BCTs in behavioural support sessions. This method has potential to add explanatory value to smoking cessation intervention outcomes.

(250 / 250 words)

Background

Behavioural interventions are typically complex, with multiple, potentially interacting, component behaviour change techniques (BCTs)[1] and modes of delivering these techniques (Craig et al., 2008; Michie, Abraham, et al., 2011; Michie et al., 2013a). BCTs are the observable, irreducible and replicable ‘active ingredients’ of an intervention that aim to alter or redirect mechanisms of action to change behaviour (Michie et al., 2016; Michie & Johnston, 2011). To describe BCTs consistently and precisely within behavioural interventions, BCT taxonomies relating to specific behavioural domains have been published (e.g. smoking cessation, BCT Taxonomy v1; Michie, Hyder, Walia, & West, 2011; Michie et al., 2013b; Michie et al., 2015).

Specifying the behaviour change techniques within an intervention has the potential to add considerable explanatory value to intervention outcomes (Abraham, 2016; Bellg et al., 2004; Borrelli, 2011; Greaves, 2014; Hankonen et al., 2014). BCT taxonomies have been used to reliably specify the presence (or absence) of practitioner-delivered BCTs in published reports, manuals, protocols, and transcripts (Lorencatto, West, Bruguera, & Michie, 2013; Lorencatto, West, Christopherson, & Michie, 2013; Lorencatto, West, Stavri, & Michie, 2012). (i.e. the delivered intervention; Lorencatto, West, Bruguera, et al., 2013; Lorencatto, West, Christopherson, et al., 2013; Lorencatto, West, Seymour, & Michie, 2013; Michie et al., 2008). However, methods have yet to be developed for characterizing the reciprocal, dynamic, and real-time nature of BCT application in interactions between practitioners and clients (Gainforth, Lorencatto, Erickson, West, & Michie, 2016; Hekler et al., 2016; Mohr et al., 2015).

By only assessing BCTs delivered by interventionists, researchers take a unidirectional view of influence in which behavioural support is done *by* interventionists *to* participants (Gainforth et

[1] Abbreviations: BCT (behaviour change technique)

al., 2016; Hagger & Hardcastle, 2014; Hardcastle, Fortier, Blake, & Hagger, 2016). Methods for reliably coding the presence or absence of practitioner-delivered and client-received BCTs in smoking cessation behavioural support sessions have been developed (Gainforth et al., 2016; Michie, Hyder, et al., 2011). However, these methods provide limited insight into intervention content, and do not account for the real-time and dynamic differences in consistency and sequences of BCT delivery and receipt.

State space grids (SSGs) are a dynamic systems method that may be well suited to characterize behavioural support interactions. SSGs are an observational, dynamic systems methodology used to map the trajectory of dyadic interactions in real time (Hollenstein, 2007; Lewis, Lamey, & Douglas, 1999). SSGs are unique in that they allow researchers to examine the reciprocal nature and bidirectional structure of interactions over time by conceptualizing individuals within a one-to-one interaction as a dynamic system (i.e. practitioner ↔ client). By treating both the practitioner's and the client's behaviour as 'one' data point or 'system', the grids create a system that allows researchers to analyse how the two actors in the system are functioning at any one moment in time. Developed in the field of developmental psychology, the SSG methodology has been used to understand various dyadic interactions such as parent-child, coach-athlete, therapist-client, and teacher-student (Erickson, Côté, Hollenstein, & Deakin, 2011; Hollenstein & Lewis, 2006; Mainhard, Pennings, Wubbels, & Brekelmans, 2012; Ribeiro, Bento, Salgado, Stiles, & Gonçalves, 2011). However, SSG methods have not been developed to characterize the reciprocal, dynamic and real-time nature of BCT delivery and receipt in behavioural support interactions.

The SSG methodology creates a graphical representation of the total state space (i.e. the range of interaction possibilities) for the system and maps the trajectory of the mutually-defined interaction through the state space in real time (i.e. moment-to-moment). It involves constructing a "state space" for the system that characterizes all possible states in which the system could function. Categories representing the practitioner's statements make up the x-axis of the grid and the categories representing the client's statements make up the y-axis of the grid. Each cell in the grid represents the potential pairing of specific statement categories by the practitioner and the client. The real-time trajectory of the system – the dyadic interaction – is mapped within the total possible state space as a series of dots connected in a sequential order in real-time (see Figure 1). Measures that capture the reciprocality (e.g., if and how each actor responds and adapts to the other) and temporality (e.g., sequences within the trajectory) of the interaction trajectory can then be quantified and compared between behavioural support practitioners. By linking these measures to intervention outcomes, research questions and hypotheses that investigate the dynamic and real-time functioning of practitioner-client dyads can be explored.

The present research aims to advance behavioural science by developing reliable methods to assess the feasibility of using the SSG methodology to characterize practitioners' delivery of and clients' responses to BCTs in smoking cessation behavioural support sessions. Specifically, this research aimed to establish proof of principle for the state space grid coding and analysis procedures and measures to characterize the frequency, sequence and duration of practitioners' delivery of and clients' verbal responses to BCTs within smoking cessation behavioural support interactions.

Methods

The study received ethical approval from the University College London departmental ethics committee and the University of British Columbia Behavioural Research Ethics Board.

Design and Participants

Six video-recordings of one-to-one routine behavioural support consultations occurring in regular practice in one UK National Health Service Stop Smoking Service were video-recorded. Of note, none of the potential participants refused to be recorded. The NHS Stop Smoking Services offers free, one-to-one behavioural and pharmacological support to individuals wanting to quit smoking (West, Walia, Hyder, Shahab, & Michie, 2010). Both practitioners were trained by National Centre for Smoking Cessation and Training and were asked to follow the same treatment manual (see www.ncsct.co.uk/). Six clients' consent to record the consultations was obtained before and after each consultation. All consultations were a pre-quit session (i.e. the client has yet to set a quit date; see Table 1). The first practitioner recorded five consultations with five different clients and the second practitioner recorded one consultation with one client. This design is similar to previous proof of principle state space grid feasibility studies in other domains (e.g. youth sport; Erickson et al., 2011) and allowed for the development of methods that could demonstrate the methods' ability characterize intra- and inter-individual differences within and between practitioners' verbal behaviour as well as differences in clients' verbal responses. Table 1 outlines the type and number video recordings used. This feasibility study investigates the degree to which the SSG method can capture intra- and inter-individual differences; it does not seek to explain these differences.

Materials

To develop the coding frameworks, the smoking cessation taxonomy was adapted to account for the verbal statements made by practitioners (Michie, Hyder, et al., 2011) and a framework for reliably categorizing clients' verbal statements in smoking cessation consultations was adapted (Gainforth et al., 2016). The practitioner coding framework includes 61 possible categories of practitioner verbal behaviour (e.g. 'facilitate goal setting') of which 53 categories represent BCTs in the smoking cessation taxonomy (Michie, Hyder, et al., 2011). The client coding framework includes 57 types of client statements (e.g. 'sets goals'), of which 50 corresponded to practitioner-delivered BCTs. Both coding frameworks and coding procedures are described below and the coding manual is presented in Supplementary File 1.

Coding Procedure

SSG investigations have generally used relatively simple coding frameworks (i.e. less than 20 categories) and coded directly from video recordings using Noldus Observer software (Noldus, Trienes, Hendriksen, Jansen, & Jansen, 2000). This software allows for the collection, management, and presentation of time-structured data from video and audio recordings. The research team initially tried to code interactions directly from video consultations. However, this approach was not practical or feasible due to the number of BCT categories in the coding framework and the complexity of the conversations (> 3 hours to code 5 minutes of interaction). To reduce coding burden, coding was adapted and conducted in two phases.

Phase 1: Coding Transcripts. Video-recordings were transcribed verbatim and divided into segments (a segment being either an uninterrupted practitioner or client statement). Two researchers (HG and FL) with prior experience of coding smoking cessation behavioural support interactions using BCT taxonomies coded each segment using the coding frameworks described above. Coders were free to assign as many categories as they wished to each segment. After each transcript was coded, inter-rater reliability was assessed using percentage agreement (Gainforth et al., 2016; Lorencatto, West, Seymour, et al., 2013; Michie, Hyder, et al., 2011). If both coders assigned the same code(s) to a segment, agreement was registered. If coders identified different code(s), disagreement was registered. To allow for an in-depth understanding of inter-rater reliability, two agreement contingency tables were created for each recording; one for the practitioner codes and one for the client codes (see Supplementary File 2). The contingency tables outline percent agreement and the pattern of agreements and disagreements between coders for all codes within the coding manual. Inter-rater reliability values of 0.60-0.79 indicate ‘substantial’ reliability and those above 0.80 would be considered ‘outstanding’ (Landis & Koch, 1977). Discrepancies were resolved through discussion, and adaptations were made to the framework to improve agreement (i.e. clarifying definitions, adding notes on alternative or additional coding where relevant).

Phase 2: Coding Video. Final, agreed codes for both the practitioner and the client were entered into Noldus Observer XT (v12). This software is designed to allow for continuous (i.e. second-by-second) observation of multiple actors from audio and/or video files (Noldus et al., 2000). Both the practitioner and client coding frameworks were entered into the software. While watching consultation videos, two researchers (KB and KO) entered the time stamp for the onset and conclusion of each code for both the client and the practitioner. To assist in entry and reduce error, the researchers observed the video three times. First, the verbal behaviour of practitioners was entered. Second, the verbal behaviour of clients was entered. Finally, the client’s and the practitioner’s non-verbal behaviour was entered (e.g. listening). The Observer software recorded the entered codes as the videos were played and created the duration-based stream of data for both the practitioner and client that is needed to conduct SSG analyses in Gridware. A video demonstration of the Observer software can be found here: https://www.youtube.com/watch?v=KeC3UGv3REc.

State Space Grid Analysis

The duration-based continuous stream of data was analysed using Gridware (Hollenstein, 2007). Gridware is state space grid software that allows for the visualization and data manipulation of multivariate time series data. Transcript coding produced two streams of time series data, one for the practitioner and one for the client. These data represent the time-stamped continuous sequential stream of behaviour exhibited by each actor during the session. Gridware was used to integrate these two streams of categorical data and create x- and y-coordinate state space grids representing each consultation. To develop methods for characterizing practitioners' delivery of and clients' response to BCTs, two indices of practitioner-client interaction dynamics were derived through several discussions amongst the research team (see Table 2): 1) reciprocality dimensions between the practitioner and the client (i.e. the degree to which the BCT delivery by the practitioner is paired with, influenced by, or dependent on statements by the client); 2) temporal patterning within the interaction (i.e. how the use of BCTs unfold through the time-course of a session). To ease interpretation of the indices and our findings, detailed descriptions of the indices and their associated measures are presented alongside findings and interpretation within the results section.

Of note, this paper represents a proof of principle. Therefore, the results aim to show the breadth and variety of state space grid analyses. Interpretations of the data and comparisons 2 are made to show how these analyses *could* be used to examine differences within and between practitioners. However, these analyses are purely exploratory and should *not* be interpreted as an explanation of how BCTs are used in practice.

Results

Coding Reliability

Across the six transcripts, researchers coded 1744 practitioner statements and 1172 client statements (see Table 1). Supplementary File 2 provides an overview of agreement statistics for both the practitioner and the client as well as contingency tables that outline agreement between the two researchers for every code within the manual. The average inter-rater reliability between coders was substantial for both the practitioner (68.58% agreement) and client (77.39% agreement). While the majority of practitioner and client codes reached levels of substantial reliability (>60% agreement; Landis & Koch, 1977), a few codes presented difficulties for coders but were resolved through discussion. For example, codes related to motivation (e.g. boost motivation and self-efficacy, facilitate consideration of reasons for wanting and not wanting to stop smoking) or general communication (e.g. providing reassurance, build general rapport, agreeing) were often discussed by clients and practitioners ambiguously and in a variety of ways. Furthermore, co-occurring codes (e.g. reflective listening alongside another code) also presented challenges as coders sometimes only coded one of the two codes present.

State Space Grids

Twelve state space grids were created from each of the six video-recorded consultations, as shown in Figure 1. In each grid, practitioner statements are represented along the x-axis and client statements are represented along the y-axis. Each data point within a specific cell in the grid represents a co-defined behavioural event (i.e., the BCT used by the practitioner and the client at that moment in time, identified as categories along the x- and y-axes). Each line connecting two data points represents a sequential transition from one co-defined behavioural event to the next. For each consultation, two grids are presented. The first grid shows all BCTs within the coding manual along each axis. The second grid shows the codes by taxonomy domains. These grids form the base foundation from which all quantitative state space grid indices were derived.

Reciprocality Indices

Reciprocality indices examined common pairings of practitioner and client statements (i.e., where in the grid the practitioner-client dyad spent their time) and how the practitioner and the client responded to each other. Three measures of reciprocality were selected to examine the consultations: 1) attractor states, 2) conditional pairing, and 3) content congruence.

Attractor states. Informed by dynamic systems concepts, attractor states represent the notion that while interactive systems (in this case, the practitioner-client dyad) could potentially function in any area of the state space grid (i.e., use all BCTs equally), most systems are drawn to particular areas of the grid (i.e., specific practitioner and client statements). This measure was selected as it identifies where the dyad spent the majority of their time and captures potentially unique dynamic qualities of each dyadic system and can be quantified in state space grids. More specifically, this measure was calculated as the duration of time the practitioner-client dyad spend in each cell within the state space grid (i.e. the sum of total duration of each specific co-defined BCT event per session). The top 10 co-defined BCT attractor state duration times for each practitioner are presented in Table 3. These data show that in interactions practitioners spent more time speaking than listening during the conversation. The client typically listens when the practitioner is speaking (i.e. conversational turn-taking). When speaking, both Practitioner 1 and 2 discuss medication and aim to promote the client's self-efficacy to quit.

The percentage of attractor state events across all taxonomy domains are shown in Table 4. These data show that Practitioner 1 spends considerably more time discussing topics unrelated to smoking cessation and listening to the client, discussing motivation to quit and adjuvant activities. Practitioner 2 did not prioritize discussing 'topics unrelated to smoking' and 'listening', but rather spent the majority of time discussing motivation to quit and adjuvant activities.

Conditional Pairing. This measure was selected as it examines clients' responses to practitioners' BCTs. It is assessed by examining common code pairings. This measure was used to determine what practitioner statements often precede client statements and vice versa. Table 5 outlines the 10 most common conditional pairings for each practitioner. Regardless of the speaker, verbal codes are most often followed by 'listening' codes. To ease interpretation and examine responses, these instances were removed. For both practitioners, clients' provision of information or discussion of adjuvant activities are preceded by congruent practitioner BCTs, whereas communication and delivery practitioner BCTs often lead the client to speak about topics unrelated to smoking cessation.

Content Congruence. This measure was selected as it examines the degree to which the practitioner and the clients' verbal behaviour are linked or matched with respect to BCT content. Given that conversational turn-taking means that one actor typically listens while the other speaks, directly concurrent assessment of behaviour will typically show incongruence (i.e. listening-speaking or speaking-listening) unless both members of the dyad are speaking at the same time. Thus, what is most indicative of true content congruence is the proportion of instances in which one member of the dyad responds congruently to the other *in their next conversational turn.* For example, if the practitioner applies the BCT 'ask about experiences of stop smoking medication', content congruence examined whether the client then subsequently responds with the corresponding code 'reports experiences of stop smoking medication' (i.e. congruence) or a different code (i.e. incongruence).

This measure was calculated by creating lagged-phase plots (see Figure 2). Lagged-phase plots are the same as standard state space grids, with the exception that the data stream for one member of the dyad (in this case, the client) is temporally offset (or "lagged") by a single behavioural event. Thus, a data point in any given cell of the lagged-phase plot represents a BCT event co-defined by the practitioner's statement at that moment in time (i.e. statement 't') and the client's *next subsequent statement* (i.e. statement 't+1'), creating pairings of practitioner BCT stimulus and client BCT response within each cell. The proportion of content congruence can be assessed from lagged-phase plots by measuring the percentage of time or frequency of co-defined BCT events in cells that represent sequentially congruent content.

For Practitioner 1, content congruence occurred 83 times (25% of total interactive statements per session) with a mean duration of 10.29 ± 2.61 seconds. Across the consultations, Practitioner 1 spent an average of 39% ± 12% of each session duration in a congruent state with the client. During Practitioner 2's session, 29% of the session duration was spent in a congruent state with 29 occurrences of content congruence (23% of total interactive statements per session) being observed and a mean duration in a content congruent state being 21.50 seconds.

Temporal Patterning Indices

Temporal patterning indices examined interaction patterns over time, the degree and manner in which practitioners use and combine multiple BCTs over the course of a consultation session. In total, four measures of temporal patterning were selected to examine the consultations: 1) variability, 2) inter-grid distance, 3) combinatory micro-patterning, and 4) sessional macro-patterning.

Variability. As with attractor states, interactive systems tend to be drawn to particular areas of grid or use of a limited set of BCTs. While attractor state measures look to identify the co-defined content of the specific BCTs to which the dyad is drawn, variability measures assess the strength and consistency of this "draw". In essence, variability measures might be considered proxies for a flexibility/rigidity dimension of practitioner-client interaction. This collection of measures examine the degree of "spread" across the total state space and the degree of movement around the grid (i.e. within-session changes in BCT use). Table 6 compares variability measures between Practitioner 1 and Practitioner 2 in terms of: 1) the range of cells utilized, 2) the number of transitions between cells, and 3) the average duration per visit across all cells. By visually inspecting the state space grids in Figure 2, the quantitative differences variability outlined in Table 6 both between and within practitioners can also be examined. Practitioner 1 used a larger number of BCTs (and the clients respond accordingly in their statements), transitions more frequently between different BCTs, and stays on a particular BCT for shorter durations of time in each instance. In contrast, Practitioner 2 used fewer BCTs (as does the client in his or her statements), made fewer transitions between BCTs and had a tendency to focus on delivering one BCT at a time for longer durations.

Inter-Grid Distance. Inter-grid distance was used to assess the degree of similarity or difference in BCT use patterns between sessions in their entirety. This measure examined the cumulative variability in system location from session to session, where each session is represented by a single grid displaying the interaction trajectory over the full course of that session. This measure is unit-less and therefore only valid for relative comparisons with trajectories on the same state space alignment and measurement scale. As long as the same grid and measurement scale are used, this measure can be used to compare within practitioner (i.e. compare one practitioner's variability across clients) or between practitioners (i.e. compare variability between two or more practitioners). For example, Practitioner 1's mean inter-grid distance across his/her five consultations (i.e. mean difference between sessions with five different clients) was 1049.41, whereas the mean inter-grid distance comparing every session of Practitioner 1 independently to Practitioner 2 was 1123.45. While these values are meaningless in absolute terms, relative comparison of these values could be used to indicate that there is approximately as much difference between sessions for Practitioner 1 with different clients as between the two practitioners. If confirmed using a larger sample of interactions, these values may suggest a tailoring and adaptation by Practitioner 1 to meet the needs of each individual client, rather than a rigid personal consulting *style* applied regardless of individual client characteristics.

Combinatory Micro-Patterning. This class of measures assesses the degree and manner in which practitioners use BCTs in combination (or not). This combinatory micro-patterning is manifested in two different aspects: 1) sequential and 2) concurrent. These measures are distinct from conditional pairings as they are not reciprocal in nature and are specific to one actor. Given that clients spent the majority of the session listening, we chose to calculate this measure only for the practitioner.

The sequential aspect examined the likelihood of the practitioner transitioning to a particular BCT, subsequent to the occurrence of a different specific BCT (i.e. if and how practitioners pair BCTs in sequence). To calculate sequential micro-patterning, lagged-phase plots were used; however, practitioners' data streams were integrated with the lagged version of the practitioners' own data stream rather than the client lagged data stream. We plot the practitioner's BCT use (i.e. statement 't') on the x-axis and the practitioner's lagged data (i.e. statement 't+1') BCT use on the y-axis. Each data point in a given cell represents the practitioner's transition from one BCT to the next BCT. Frequencies of all possible transitional pairings can then be calculated from this lagged phase plot for each consulting session. Table 7 provides the top 10 lagged-phase BCT sequences for each practitioner. These data indicated that Practitioner 1 rarely used two BCTs in sequence. Rather, Practitioner 1 applied a BCT and then listened to the client's response. Practitioner 2 also followed this pattern of listening and then applying one BCT, however Practitioner 2 delivered 'Provide normative information about others' behaviour and experiences' in sequence with other BCTs.

The concurrent aspect examined the degree to which practitioners used multiple BCTs *at the same time*. It represents practitioners combining BCTs in a way that allows them to achieve multiple objectives within the same utterance. To calculate the degree of concurrent use of multiple BCTs by practitioners, a state space grid is constructed where the primary BCT in any verbal utterance is plotted on the x-axis and the secondary or concurrent BCT, if any, is plotted on the y-axis. Thus a data point in a given cell represents concurrent pairing of two BCTs, or a singular BCT if the y-axis category is “none”. When the trajectory of any consulting session is tracked on this grid, the frequency of singular vs. concurrently expressed BCTs can be calculated and patterns of concurrent use can be identified. In the sessions, Both Practitioner 1 and Practitioner 2 were similar in their overall concurrent use of multiple BCTs (Practitioner 1 mean = 15.6% of total BCT events [range = 7% - 19%]; Practitioner 2 = 17 % of total BCT events). However, Practitioner 1 used a much larger variety of concurrent combinations of BCTs, averaging 26.6 different concurrent BCT combinations per session (range = 16-33) and used 78 unique concurrent BCT combinations over the course of the five sessions, which may suggest an adaptive and nuanced layering of BCT implementation (see Figure 3 for example SSG grids). In contrast, Practitioner 2 used only 10 different concurrent BCT combinations in total, appearing much more constrained and structured in his/her BCT usage. With respect to the specific BCTs combined concurrently by both practitioners, Supplementary File 3 lists the top 10 most frequent combinations exhibited by Practitioner 1 and the only 10 used by Practitioner 2.

Sessional Macro-Patterning. This measure was used to examine the temporal patterning (i.e., early, middle, late) of the systems BCT use by function category. Specifically, it examined when the dyad *first* used a BCT category. Supplementary File 3 provides a comparison of time to first entry for each BCT function category. Both practitioners’ first used BCTs related to ‘general communication’, ‘other topics unrelated to smoking cessation’ ‘communication’, ‘information gathering’ and ‘addressing motivation’ occurred early in the conversation (i.e. < ~1.3 minutes to first occurrence). Both practitioners then discussed ‘maximising self-regulatory capacity/skills’, and ‘promote adjuvant activities’ later in the conversation (i.e. > ~4 minutes to entry). The practitioners differed in when they first applied techniques focusing on ‘delivery of the intervention’; Practitioner 1 first used BCTs related to delivery later in the conversations whereas Practitioner 2 first used these BCTs earlier in the conversation.

Discussion

Reliable dynamic systems coding procedures, methods and measures were established to characterize the frequency, sequence and duration of practitioners’ BCT delivery and clients’ verbal responses within smoking cessation behavioural support interactions. To our knowledge, this is the first application of the state space grid methodology within the BCT literature and the first example of a method to characterize the real-time application of BCTs. The coding procedures and indices developed establish a method for examining reciprocality dimensions and temporal patterning of BCT delivery and receipt between smoking cessation practitioners and clients. The analyses are purely exploratory and should *only* be used to understand the application of state space grids as a method. Below we discuss how our findings can be used to characterize behavioural support sessions within and beyond smoking cessation and the implications of the SSG method for advancing behavioural science.

Characterizing Behavioural Support Sessions

A primary application of this method would be to create practitioner profiles that could be used to explain the outcomes of an intervention. Given our limited sample size, we are not in the position to make inferences about BCT application. However, if confirmed with further recordings, our indices could be used to suggest that while both practitioners were the primary drivers of their consulting sessions with clients (i.e. speaking more), Practitioner 1 appeared to create a more interactive and dynamic interactions rather than using a lecture-based format. In so doing, s/he may have been able to consistently encourage alignment and joint focus between him/herself and the client (e.g. reciprocality indices). Practitioner 1 also appeared to utilize a more adaptive intervention style, modifying his/her BCT use to align with different clients rather than following a rigid script-style intervention format (e.g. temporal patterning indices). Temporal patterning indices also give the impression that Practitioner 1 employed a dynamic intervention approach rather than a step-by-step checklist approach. S/he often layered several BCTs within the same utterance to address multiple intervention goals at the same time and spent time using relational/rapport-building elements *prior to* addressing intervention content such as goal setting. At this point, these profiles cannot be linked to outcomes and need to be confirmed with further recordings, but they are noteworthy in that they illustrate how the proposed indices may be used to capture, represent and understand potential differences in the delivery of BCTs in behavioural support interactions.

Our findings indicate that both practitioners applied BCTs sequentially and concurrently. When applied concurrently, one BCT tended to relate to content of the intervention (e.g. goal setting) and one technique tended to relate to the interpersonal style used to deliver the technique (e.g. reflective listening, providing reassurance). If confirmed with further recordings, these findings align with research indicating that techniques can be classified in terms of content or interpersonal style and highlight the need for further research to understand the relationship between interpersonal style and intervention content (Hardcastle, 2016; Hardcastle et al., 2016).

Value of the State Space Grid Methodology for Behavioural Science

The SSG method could provide a more nuanced understanding of the complexity and variability of BCT application both within- and between-practitioners than previous BCT analyses methods that have only accounted for the presence or absence of BCTs in an intervention (Leventhal & Friedman, 2004; Michie, 2005). The dynamic systems-informed method is valuable in that it can be used to examine variability in practice and can be used to understand *when, how* and in *what sequence* practitioners apply BCTs as well as to understand how practitioners *tailor* BCTs to clients' responses. Other methods try to minimize and control statistical "noise". Whereas, in SSG methods variability and its practical manifestations become the intentional target of analysis. By quantifying real-time adaptations and adjustments of back-and-forth interactions in behavioural support interventions, the variability in practitioners' practice and clients' responses can be examined.

The ability to understand variability in practitioners' BCT application and clients' responses has potential to add explanatory value to smoking cessation intervention outcomes as well as behavioural interventions more broadly. Using the current method, reciprocality and temporal patterning indices could be linked to practitioners' quit rates. These analyses could be used to understand effective BCT application in smoking cessation. More broadly, researchers could use the methods outlined in this paper to create SSG coding and analysis methods for other behavioural domains (e.g. diet, physical activity, alcohol consumption). Together these methods and indices would allow researchers to develop a nuanced understanding of what differentiates more and less effective practitioners in terms of their BCT application interaction patterns. Findings from such research could inform recommendations for service monitoring, training and evaluation of stop smoking practitioners.

Limitations and Future Directions

This study had several limitations. First, we only examined six consultations, from two practitioners, working in one stop smoking service. The process of coding sessions is very resource intensive and it was considered important to begin with a test of whether the method can be applied reliably. This sample size was sufficient to establish proof of principle of the state space grid coding procedures and measures, however our findings should *not* be interpreted as an explanation of how BCTs are used in practice. Larger sample sizes and further applications of the SSG methods are needed. Behavioural science is beginning to harness the power of artificial intelligence and machine learning (Michie et al., 2017). It is possible, using natural language processing systems that in future the coding of sessions will be able to be largely automated and that will open up and advance an important area of research. Second, we did not examine an exhaustive list of SSG measures. Future studies with larger samples may aim to extend and refine the current study measures. Third, we only coded the presence or absence of practitioners' BCT application and clients' responses. The procedures did not assess the quality of the practitioners' BCT delivery nor qualify clients' responses. Collecting this information would provide further characterization of the interaction but would require extensive method development. Fourth, we did not code non-verbal communication, with the exception of listening or recording information. Future research should consider how non-verbal communication could provide further understanding as to how practitioners apply BCTs and establish rapport with clients. Despite coding procedures being developed and tested by two highly-trained BCT coders in the area of smoking cessation, there were challenges to the method. Further dynamic systems research is needed to adapt methods for researchers of various backgrounds using a variety of BCT taxonomies.

Conclusions

This study established the first published coding methods and measures for investigating the dyadic interaction between the practitioner and client in smoking cessation behavioural support interventions. The method provides the basis for investigating reciprocality and temporality of BCT delivery and receipt in behavioural support interactions and may improve descriptions and analyses of real-world BCT application.

Table 1. Consultations

Recording	Practitioner	Stage of Quitting	Total Time (min)	Practitioner Statements (n)	Client Statements (n)	Overall % Positive Agreement	Practitioner % Positive Agreement	Client % Positive Agreement
1	A	Pre-quit	38.61	268	182	70.22	61.57	82.97
2	A	Pre-quit	42.18	294	231	66.48	63.95	69.70
3	A	Pre-quit	29.05	323	223	78.57	74.30	84.75
4	A	Pre-quit	35.63	363	258	69.89	69.97	69.77
5	A	Pre-quit	37.78	360	219	76.86	70.28	87.67
6	B	Pre-quit	35.33	136	59	70.26	70.59	69.49

Table 2. Reciprocality and Temporal Patterning Measures

Measure	Indices	Research Question	Measure Description	Analytic Approach
Attractor states	Reciprocality	What are the most prevalent practitioner-client interaction states?	Identification of co-defined interaction states to which the dyad is drawn.	Comparisons of duration of time spent in, or frequency of visits to, different cells or regions of the state space.
Content congruence	Reciprocality	How aligned are practitioner and client's interactive behaviour?	Percentage of total interactive states in which the practitioner and client exhibit congruent interactive behaviour sequentially (i.e. turn-taking discussion).	Percentage of time duration spent in, or frequency of visits to cells representing sequentially occurring content agreement between practitioner and client behaviour.
Conditional pairing	Reciprocality	How do clients respond to the practitioner's BCTs and vice versa?	Most prevalent client responses paired with specific practitioners' BCTs (i.e. if x BCT, then y response).	Comparisons of time duration spent in specific practitioner BCT – client response sequential states.
Variability	Temporal Patterning	How consistently patterned are practitioner-client interaction trajectories?	Degree of variability across the total state space, within a particular session.	Whole grid measure of dispersion reflecting relative usage of the full state space (accounting for size of the state space and frequency/duration of visits to any given cell). This measure is also defined by the range of cells utilized, the number of transitions between cells, and the average duration per visit across all cells.
Inter-grid distance	Temporal Patterning	How similar/consistent	Cumulative variability in	Whole grid measure of the absolute value of

		are practitioners? Can we detect between and within practitioner differences?	system location from one session to another.	the sum of the difference in duration for every cell between one trajectory (i.e. session) and another trajectory.
Combinatory Micro-Patterning	Temporal Patterning	In what combinations do practitioners employ and link multiple BCTs (sequentially or concurrently)?	*SEQUENTIAL:* Likelihood of transition to a particular BCT, subsequent to the occurrence of a given other BCT. *CONCURRENT*: Co-occurrence of two BCTs simultaneously in the same utterance.	*SEQUENTIAL:* Comparison of frequency of visits to different cells in lagged phase plot, in which practitioner BCT forms the x-axis and the following practitioner BCT (i.e. x + 1) forms the y-axis; each cell represents a sequential transition from one BCT to another. *CONCURRENT:* Comparison of frequency of visits to different cells in a plot in which practitioner primary BCT forms the y-axis and practitioner concurrent BCT (if any) forms the x-axis.
Sessional macro-patterning (cell/region)	Temporal Patterning	Do consulting sessions unfold in patterned sequences of interaction content?	Establish within-session temporal patterning (i.e. early, middle, late) of practitioner's BCT.	Comparison of time to first entry within sessions for BCT function category clusters.

Table 3. Top 10 Attractor States Across All BCT Codes

Practitioner 1		**Practitioner 2**	
Concurrent State (Practitioner-Client)	Duration in Seconds (Mean±SD)	Concurrent State (Practitioner-Client)	Duration in Seconds
1. A01-Listening	310.95 ± 85.59	1. Listening-Listening	474.20
2. M05-Listening	242.10 ± 142.67	2. M05-Listening	442.48
3. Listening-O01	104.42 ± 186.13	3. A01-Listening	327.68
4. I09-Listening	85.95 ± 34.66	4. A03-Listening	148.24
5. M12-Listening	84.61 ± 26.27	5. D02-Listening	121.56
6. C10-Listening	73.53 ± 27.37	6. M01-Listening	92.72
7. D02-Listening	69.01 ± 36.70	7. I09-Listening	62.16
8. C04-Listening	62.62 ± 17.89	8. O05-Listening	38.6
9. M01-Listening	60.15 ± 23.51	9. C01-Listening	37.92
10. C01-Listening	58.60 ± 44.55	10. Listening-A01	31.96

Note. M01 – Provide information on consequences of smoking and smoking cessation, M05 – Provide normative information about others' behaviour and experiences, M12 – Biofeedback, A01 – Advise on stop-smoking medication, A03 – Adopt appropriate local procedures to enable clients to obtain free medication, D02 – Emphasise choice, I09 – Explain how tobacco dependence develops, C01 – Build general rapport, C04 – Explain expectations regarding treatment programme, C10 – Provide reassurance, O01 – Other, O05 – Scheduling and administration.

Table 4. Percentage Total of Attractor States Across BCT Domains

Practitioner Domain	Practitioner 1 Mean % of total events/session	Practitioner 2 % of total events
Motivation	15 ± 4	17
Information	7 ± 1	11
Adjuvant Activities	12 ± 3	13
Communication	17 ± 5	12
Self-regulatory	3 ± 2	2
Delivery	2 ± 1	10
Other	44 ± 10	36

Table 5. Content Congruence as measured by the top 10 conditional pairings

Practitioner 1		Practitioner 2	
Conditional Pairing (Practitioner-Client)	Frequency of Occurrence (Mean±SD)	Concurrent State (Practitioner-Client)	Frequency of Occurrence
1. A01-A01	7.20 ± 6.42	1. I01-I01	5
2. I03-I03	6.60 ± 2.41	2. I03-I03	3
3. I01-I01	3.40 ± 2.07	3. A01-A01	2
4. C07-I03	2.80 ± 1.92	4. D02-A01	2
5. O06-O06	2.80 ± 2.77	5. M05-O02	2
6. M10-M10	2.60 ± 1.67	6. D01-O02	2
7. O05-O05	2.40 ± 1.82	7. I01-I01	5
8. C07-I01	2.00 ± 1.22	8. I03-I03	3
9. C01-C01	1.80 ± 1.30	9. A01-A01	2
10. M05-M05	1.60 ± 2.07	10. D02-A01	2

Note. M01 – Provide information on consequences of smoking and smoking cessation, M05 – Provide normative information about others' behaviour and experiences, M10 – Facilitate consideration of reasons for wanting and not wanting to stop smoking, A01 – Advise on stop-smoking medication, D01 – Tailor interactions appropriately, D02 – Emphasise choice, I01 – Assess current and past smoking behaviour, I03 – Assess past history of quit attempts, C01 – Build general rapport, C07 – Use reflective listening, O02 – Agree, O05 – Scheduling and administration, O06 – Uncodeable.

Table 6. Variability

	Cell range	**Total transitions**	**Duration per visit** (seconds)
Practitioner 1 (Mean ± SD)	58.60 ± 3.65	327.80 ± 57.98	6.62 ± 1.19
Practitioner 2	42	127	16.53

480 **Table 7. Top 10 Lagged-Phase Practitioner BCT Sequences**

Practitioner 1		Practitioner 2	
Sequence (P-P Lag)	Frequency of Visits (Mean±SD)	Sequence (P-P Lag)	Frequency
1. O07-A01	15.20±9.83	1. O07-A01	8
2. O07-C07	14.20±5.12	2. O07-C07	5
3. A01-O07	11.80±7.82	3. I01-O07	5
4. O07-O07	11.60±5.03	4. D02-O07	5
5. O01-O07	10.60±12.97	5. O07-C01	4
6. O07-O01	10.60±14.62	6. A01-M05	4
7. C07-O07	8.60±4.67	7. O07-I01	4
8. I03-O07	6.80±2.68	8. M05-D02	4
9. M05-O07	6.40±3.21	9. A01-O07	3
10. O07-C01	6.40±2.70	10. O07-O07	3

481 *Note.* M05 – Provide normative information about others' behaviour and experiences, A01 – Advise on stop-smoking
482 medication, D02 – Emphasise choice, I01 – Assess current and past smoking behaviour, I03 – Assess past history of
483 quit attempts, C01 – Build general rapport, C07 – Use reflective listening, O01 – Other, O07 – Nonverbal.

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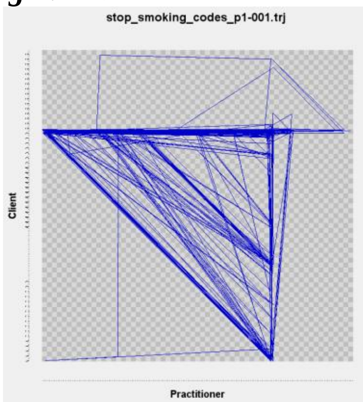
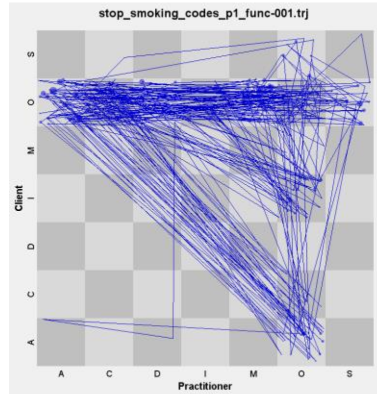
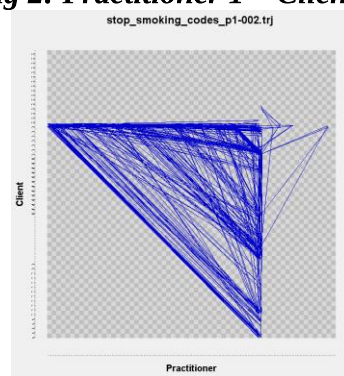
Figure 1. Raw State Space Grids

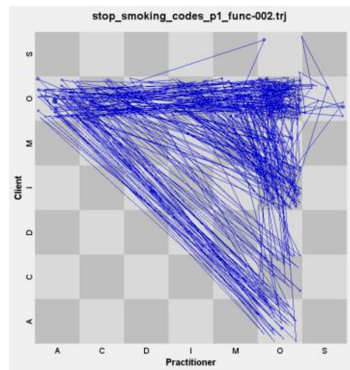
Recording 1: Practitioner 1 – Client 1



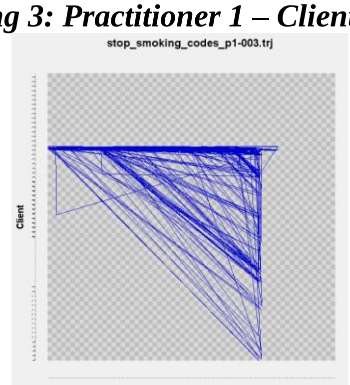


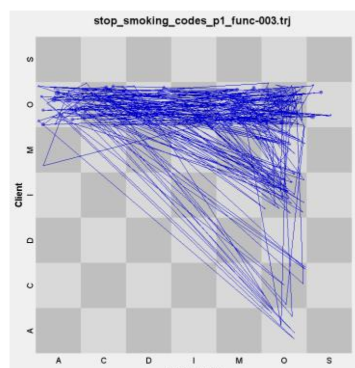
Recording 2: Practitioner 1 – Client 2



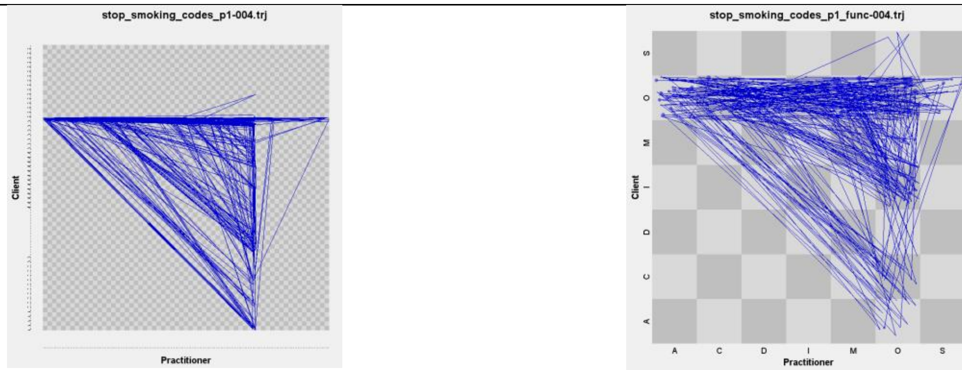


Recording 3: Practitioner 1 – Client 3

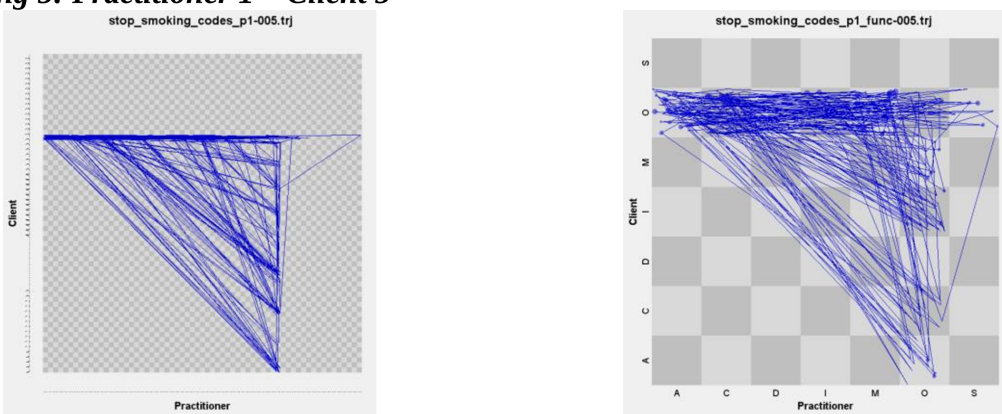




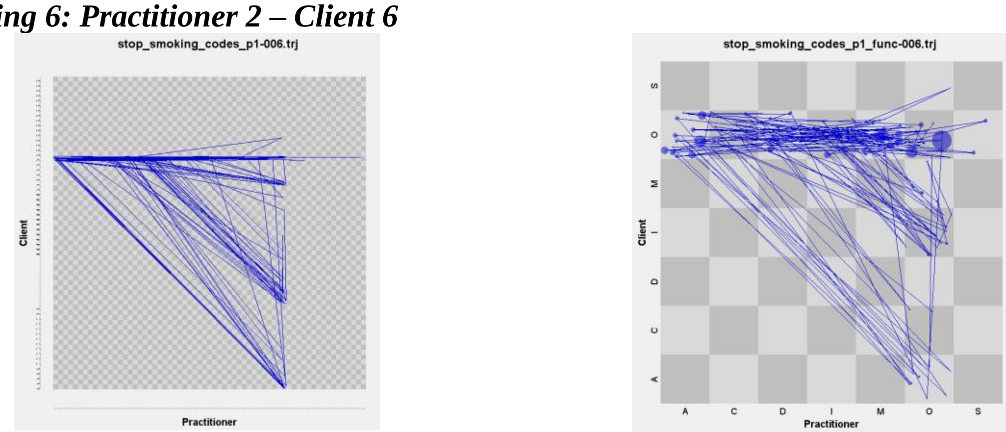
Recording 4: Practitioner 1 – Client 4



Recording 5: Practitioner 1 – Client 5



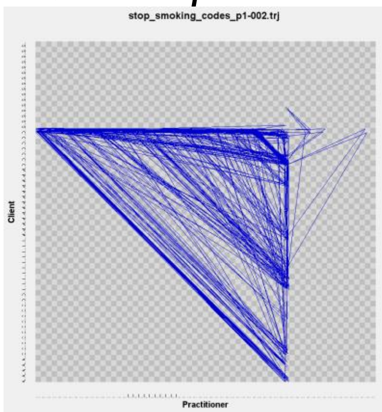
Recording 6: Practitioner 2 – Client 6



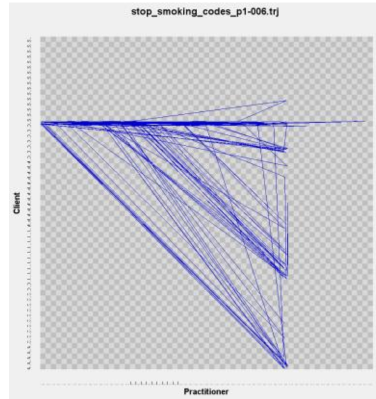
Note. For each recording two grids are presented. The first grid shows all BCT codes. The second grid shows collapsed by taxonomy domains: motivation (M), self-regulatory (S), adjuvant (A), communication (C), delivery (D), Information (I), Other (O).

Figure 2. Content Congruence Lagged Phased Plots

Lagged Phased Plots for All BCT Codes

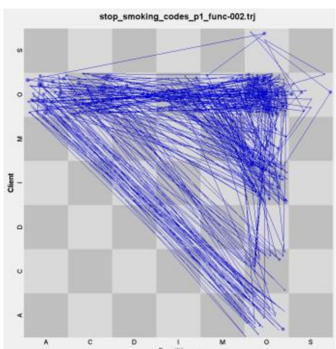


Practitioner 1

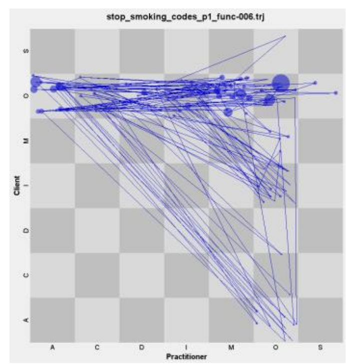


Practitioner 2

Lagged Phased Plots Collapsed Across Domain



Practitioner 1

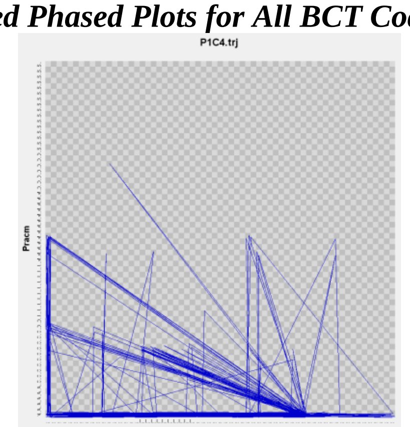


Practitioner 2

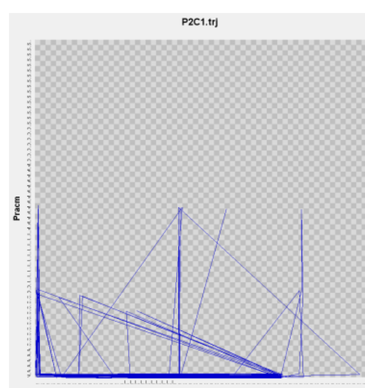
Note. Taxonomy domains: motivation (M), self-regulatory (S), adjuvant (A), communication (C), delivery (D), Information (I), Other (O).

Figure 3. Examples of Concurrent BCT Combination Use

Lagged Phased Plots for All BCT Codes



Practitioner 1 – Client 4



Practitioner 2 – Client 6

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