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Evaluating the effect of health warnings in influencing Australian smokers' psychosocial and quitting behaviours using fuzzy causal network

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Abstract

This paper explores the application of fuzzy causal networks (FCNs) to evaluating effect of health warnings in influencing Australian smokers' psychosocial and quitting behaviour. The sample data used in this study are selected from the International Tobacco Control Policy Evaluation Survey project. Our research findings have demonstrated that new health warnings implemented in Australia have obvious impacts on smokers' psychosocial and quitting behaviours. FCN is a useful framework to investigate such impacts that overcome the limitation of using traditional statistical techniques, such as linear regression and logistics regression, to analyse non-linear data.

Keywords

Fuzzy causal network; knowledge discovery; decision support; public health; tobacco control

1. Introduction

Tobacco use control has gradually become a global public health issue since cigarette smoking was recognised as a leading cause of death around the world (Boyle, Gray, Henningfield, Seffrin, & Zatonski, 2004). Almost every jurisdiction in the world joins tobacco control battles and enormous efforts, including policy interventions, mass media campaigns and the provision of smoking cessation information, to cope with the problem (David, 2000). Among them, regulating the packaging and labelling of tobacco products to inform consumers about the risk of smoking is one of key policies proposed by the Framework Convention and Tobacco Control (FCTC) – the first international treaty devoted to public health (FCTC, 2003). Many countries, such as UK have increased the size and contrast of its warnings since 2003; in Australia, the warning labels have moved from moderately large text-based warnings to larger graphic warning since 2006 (Borland et al., 2009b). Accordingly, evaluating the effect of such policies effectively and accurately has

become an important research topic, since this can provide important feedback to decision-makers to refine existing policies or develop new policies in order to get better outcomes.

The International Tobacco Control Policy Evaluation Survey (ITC) (ITC, 2002) is an international research and evaluation project. It aims to evaluate the psychosocial and behavioural impact of key national-level tobacco control policies over time. The ITC project provides a cohort survey data, collected from many countries including UK and Australia, for studying the impact of varying forms of health warnings and of changes in warnings across these countries. Up to now many good results from that project have been reported, majority of analyses is based on traditional statistical techniques, such as linear regression analysis and logistic regression analysis (Borland et al., 2009a, 2009b). However, considerable research outcomes have demonstrated that although these traditional statistical models are very useful in monitoring and evaluating the impact of individual factor, they have fundamental limitations due to their inability to account for non-linear data relationships that may characterise many aspects of the tobacco domain (Borland et al., 2009a,b; Hammond, Fong, McNeill, Borland, & Cummings, 2006; Hammond et al., 2007). As a result, significant gaps remain in our understanding of if and how health warnings have their effects, in particular whether there are unreported non-linear data relationship between the strength of health warnings and smokers' psychosocial and quitting behaviours.

FCN is a dynamic networked system with feedback (Zhang, Liu, & Zhou, 2006; Zhou, Liu, Zhang, 2006) that is an extension of fuzzy cognitive map (Kosko, 1986). It can be used for knowledge discovery and decision support in the environment of uncertain and incomplete information. The existing applications of FCN in a range of different areas, such as stock investment analysis (Koulouriotis, Diakoulakis, & Emiris, 2001), knowledge processing (Taber, 1991) and strategic planning (Tsadiras, Margaritis, & Mertzios, 1995), have demonstrated that FCN is useful in modelling non-linear data relationships, especially in the cases where strong interaction among various variables are involved. Here we report an exploration of the application of FCN method to address the gap above. FCN is applied to evaluate the effect of new warning labels on cigarette packs in influencing Australian smokers' psychosocial and quitting behaviours over time. The data used in this study are selected from five survey waves provided by the ITC project.

This paper is organised as follows. Section 2 provides a brief description of FCN and its causal inference mechanism that will be used in our study. Section 3 builds an FCN-based model towards to evaluating the effect of warning labels on cigarette packs in influencing Australian smokers' psychosocial and quitting behaviours. Section 4 applies the specific FCN-based model and relevant causal inference mechanism to identify useful inference patterns. Section 5 discusses the main research findings. Section 6 makes concluding comments.

2. Brief description of fuzzy causal network and its causal inference mechanism

Mathematically, an FCN can be described as a dynamic (time dependent) fuzzy direct graph $\Omega = (V, A)$, where V is the set of vertices and A is the set of directed arcs of Ω . Here each

vertex represents a fuzzy event, such as smokers' quitting behaviour; tobacco industry's response to tobacco control policies; and so on. Each directed arc from one vertex to another one represents a possible causal relationship from the former to the latter. By convention, we use $v_i \in V$ to denote the vertices of Ω , where $i = 1, 2, \dots, n$, and $n = |V|$ is the number of vertices of Ω . If v_i has some causal influence on v_j at time t then a directed arc (v_i, v_j) is drawn from v_i to v_j . The dynamics of this FCN depends upon its vertex states that vary with time. Associated with each v_i is a vertex state value $x_i(t) \in [0, 1]$, which specifies the degree that the fuzzy event occurs at a discrete time t . At each vertex there is a vertex function f_i that transforms the total inputs received by this vertex into its next state value $x_i(t+1) \in [0, 1]$. After constructing an FCN for the purpose of tobacco control, we can perform a quantitative simulation for a specific problem.

The main causal inferences of FCN that will be used in this paper are as follows. For any two distinct vertices $u, v \in V$, if we use $\rho = \rho(u, v)$ to represent a directed path from u to v , then the directed path is defined as a sequence $v_1, v_2, \dots, v_r$ of distinct vertices of Ω , such that $v_1 = u, v_r = v$ and (v_i, v_{i+1}) is a directed arc of Ω for each $i = 1, 2, \dots, r-1$. If we use $I_\rho = I_\rho(u, v)$ to represent the indirect effect u influences v along the directed path $\rho = \rho(u, v)$, then

$$I_\rho = \prod_{(y,z) \in A(p)} x_y(t) \cdot w_{yz}(t) \quad (1)$$

where $A(p)$ is the set of directed arcs on the directed path $\rho(u, v)$, $x_y(t)$ is the state of vertex y at time t , and $w_{yz}(t)$ is the weight associated with the directed arc (y, z) on the path $\rho(u, v)$. If the directed path $\rho = \rho(u, v)$ consists of two vertices only, then $I_\rho = I_\rho(u, v) = x_y(t) \cdot w_{yz}(t)$ represents the direct effect u influences v . If we use $\Phi = \Phi(u, v)$ to represent the set of all directed paths $\rho = \rho(u, v)$ from u to v , $T_\rho = T_\rho(u, v)$ to represent the total effect u influences v along all possible directed paths from u to v , then

$$T_\rho = \prod_{u_i \in N-(v)} \max_{\rho \in \Phi(u, u_i, v)} I_\rho(t)$$

where $N-(v)$ is the set of all existing vertices u_i such that there exists a directed arc of Ω from u_i to v . $\Phi = \Phi(u, u_i, v)$ represents the set of all directed paths $\rho = \rho(u, u_i, v)$ from u to v which passes u_i .

3. A fuzzy causal network-based model building

3.1. Data processing and basic characteristics of the processed data

First, the ITC survey (ITC, 2002) asks smokers a range of questions about their smoking and the impact of policies designed to affect their smoking. It also asks about quitting activity, and uses the data from one wave to predict this in the next wave. Some questions of interest here were asked on wave 2 to wave 6 but not on wave 1, therefore we selected four data sets from wave 2 to wave 6. Throughout the paper, we use W_i ($i = 2, 3, 4, 5, 6$) to represent five survey waves within the ITC project, and $W_{2-i} = W_2 + W_3 + \dots + W_i$ ($i = 3, 4, 5, 6$). The four data sets are: W_{2-3} ($n = 1458$); W_{3-4} ($n = 1477$); W_{4-5} ($n = 1260$); W_{5-6} ($n = 1350$),

respectively. Four data sets were selected for Australia only, and each data set represents the participants, who are smokers at W_i , participated in the survey at that wave and W_{i+1} .

Second, we constructed four attributes or variables (see Table 1): “*salience* (based on answers to 2 questions on noticing and reading health warnings), *avoidance* (on 4 actions to avoid health warnings), *cognitive* (2 questions on perceptions of smoking risk and thoughts of quitting) and *forgoing* (one question on not smoking a cigarettes as a result of noticing the warnings) as the input attributes, which represent smokers’ representative responses to health warnings. The rate of attempting to quit at the next survey wave is selected as the output attribute. We aim to study the possible relationships among all input attributes and between the input attributes and output attribute, and replicate this across four wave-to-wave transitions.

3.2. Constructing a fuzzy causal network that consists of salience, avoidance, cognitive, foregoing and make a quit attempt

First, we use v_i ($i = 1, 2, 3, 4$) to represent the response to *salience*, *avoidance*, *cognitive* and *forgoing*, which are chosen from W_i . We use v_5 to represent the status of make a quit attempt, which is chosen from W_{i+1} . The possible values of v_1, v_2, v_3, v_4 at W_i and v_5 at W_{i+1} are as follows:

$$v_1 \in \{1, 2, 3\} = \{\text{never or rarely; sometimes; very often}\}$$

$$v_2 \in \{1, 2, 3\} = \{\text{no; yes}\}$$

$$v_3 \in \{1, 2, 3\} = \{\text{never or a little bit; somewhat; a lot}\}$$

$$v_4 \in \{1, 2\} = \{\text{no; yes}\}$$

$$v_5 \in \{1, 2\} = \{\text{no; yes}\}$$

The basic information about, and possible bivariate association among, v_1 (*salience*), v_2 (*avoidance*), v_3 (*cognitive*), v_4 (*forgoing*) and v_5 (*make a quit attempt*), are summarised as in Tables 2–5.

Second, we use $\Omega = (V, E)$ to represent FCN, where $V = \{v_1, v_2, v_3, v_4, v_5\}$, E is the set of directed arcs between any two vertices. For v_1 and v_3 , we use a simple linear fuzzy membership function to scale three levels of responses to 0.33, 0.66, 1, which represents the degree of that fuzzy event at any time t ; for v_2 and v_4 , we transfer the binary values to 0 and 1, and in this case, we take the two concepts as the special case of fuzzy events. As a result, the possible state values of the four input vertices can be specified as follows:

$$x_1(t) = \{x_{11}(t), x_{12}(t), x_{13}(t)\} = \{0.33, 0.66, 1\}$$

$$x_2(t) = \{x_{21}(t), x_{22}(t)\} = \{0, 1\}$$

$$x_3(t) = \{x_{31}(t), x_{32}(t), x_{33}(t)\} = \{0.33, 0.66, 1\}$$

$$x_4(t) = \{x_{41}(t), x_{42}(t)\} = \{0, 1\}$$

Third, we specify the causal relationship from one vertex to another vertex. We commence with the information shown in Table 3, which demonstrated that when smokers' response to salience increases from a lower to a higher level (i.e., never or rarely $\rightarrow$ sometimes $\rightarrow$ often or very often) at W_i , the probability that the smoker will make a quit attempt at W_{i+1} increases. In this case we interpret the responses, as showing that there is positive causal relationship from v_1 to v_5 over five years. Tables 3 and 4 or Table 5 follow the same procedures above, to show that there are positive causal relationships from v_1 to v_2 , v_1 to v_3 , v_1 to v_4 , v_1 to v_5 , v_2 to v_3 , v_2 to v_4 , v_2 to v_5 , v_3 to v_4 , v_3 to v_5 , and v_4 to v_5 over five years. Accordingly, we construct a fuzzy causal network as a new framework to investigate the possible relationship among these interrelated variables, which is shown in Fig. 1.

Among five vertices " v_1 (at W_{2-5}), v_2 (at W_{2-5}), v_3 (at W_{2-5}), v_4 (at W_{2-5}) and v_5 (at W_{3-6})" in this FCN, v_1 (at W_{3-5}) is the initial vertex, which is regarded as the input of a simplified tobacco control system that consists of the five vertices above. v_5 (at W_{3-6}) is the terminal vertex, which is regarded as the output of the same system. While v_2 (at W_{2-5}), v_3 (at W_{2-5}) and v_4 (at W_{2-5}) are regarded as the middlewares. This implies that the responses for the three questions are influenced by the responses to v_1 (at W_{2-5}), whilst at the same times, the responses for the three questions are interrelated and influence the responses to v_5 (at W_{3-6}). The state value of the initial vertex v_1 (at W_{2-5}) is determined by some external stimulus, such as the size of warning labels on cigarette packs.

Fourth, we estimate the weight of the effect of one vertex on another vertex for any participant at any time t . Suppose that for two distinct vertices $v_i = \{v_{i1}, v_{i2}, \dots, v_{ik}\}$ and $v_j = \{v_{j1}, v_{j2}, \dots, v_{jk}\}$ ($i, j = 1, 2, \dots, n+1$), any participant at any time t will give answers $l_i \in \{v_{i1}, v_{i2}, \dots, v_{ik}\}$ and $l_j \in \{v_{j1}, v_{j2}, \dots, v_{jk}\}$ to them. We selected the real number $w_{ij} \in [-1, 1]$, which was transferred from the row % located in l_i th row and l_j th column, as the weight of v_i influences v_j for that specific participant at time t . For example, from Table 4 we can see that for two distinct vertices v_1 and v_3 , if a smoker at W_{2-5} gives responses 1 (never or rarely) to v_1 and 1 (not at all or a little)/2 (somewhat)/3 (a lot) to v_3 , then we can find out that the row % located in 1th row and 1th/2th/3th column for that specific smoker are 70.8%/74.8%/72%/69.5%, 24.9%/23.3%/25.7%/ 25.4%, 4.3%/1.8%/ 2.3%/5.1%, respectively. Then we transfer such a row association to real numbers, which are

0.708/0.748/0.72/0.695, 0.249/0.233/0.257/0.254, 0.43/0.18/0.23/0.51, as the weights of v_1 influence v_3 for that specific smoker at W_{2-5} , respectively. From Section 3.1 we can see that, there are three responses for v_1 ; 2 responses for v_2 ; 3 responses for v_3 ; and 2 responses for v_4 . Then, there are 36 ($3 \times 2 \times 3 \times 2 = 36$) cases (combination of responses) with which smokers are associated. Using Tables 3 and 4 or Table 5 and repeating the same procedure above, we can estimate weights of the influence of one vertex on another one for all possible cases with which smokers are associated. In different cases with which smokers are associated, the weight of the influence of an initial vertex on another terminal vertex at a different time t can be quite different.

4. Performance evaluation

In Australia, the warning labels moved from moderately large text-based warnings to larger graphic warning in 2006, between W_4 and W_5 . We take this as an external stimulus of the initial vertex v_1 , and we aim to investigate how the new warning labels influenced smokers' quitting behaviours over time, and what were the difference of such effects between before and after that new warning labels were implemented. More specifically, we investigate whether, when v_1 (at W_{2-5}) increased from a lower to a higher level (i.e., never or rarely $\rightarrow$ sometimes $\rightarrow$ often or very often) over five years (from W_2 to W_5), how it influences v_2 (at W_{2-5}), v_3 (at W_{2-5}), v_4 (at W_{2-5}) and v_5 (at W_{3-6}) directly and indirectly; how v_1 (at W_{2-5}), v_2 (at W_{2-5}), v_3 (at W_{2-5}) and v_4 (at W_{2-5}) interacted with each other to influence v_5 (at W_{3-6}) over five years. In order to determine whether the new warning labels influenced smokers' quitting behaviours of smokers over five years, we examine whether this is revealed by shifting data patterns.

First, according to the causal inference mechanism mentioned in Section 2, the direct impact of v_1 (at W_{2-5}) on v_2 (at W_{2-5}), v_3 (at W_{2-5}), v_4 (at W_{2-5}) and v_5 (at W_{3-6}) at any time t can be measured by $x_1 \cdot w_{1j}$ ($j = 2, 3, 4, 5$).

Second, from Fig. 1 we can see that there are eight directed paths from v_1 to v_5 :

$$\rho_1=(v_1;v_5); \rho_2=(v_1;v_2;v_5); \rho_3=(v_1;v_3;v_5); \rho_4=(v_1;v_2;v_3;v_5); \rho_5=(v_1;v_4;v_5); \rho_6=(v_1;v_2;v_4;v_5); \rho_7=(v_1;v_3;v_4;v_5); \rho_8=(v_1;v_2;v_3;v_4;v_5):$$

The indirect and total impacts of v_1 (at W_{2-5}) on v_5 (at W_{3-6}) along the eight directed paths above at any time t can be measured as follows:

$$I_1=x_1 \cdot w_{15}$$

$$I_2=(x_1 \cdot w_{12})(x_2 \cdot w_{25})$$

$$I_3=(x_1 \cdot w_{13}) \cdot (x_3 \cdot w_{35})$$

$$I_4 = (x_1 \cdot w_{12}) \cdot (x_2 \cdot w_{23}) \cdot (x_3 \cdot w_{35})$$

$$I_5 = (x_1 \cdot w_{14}) \cdot (x_4 \cdot w_{45}) \quad (3)$$

$$I_6 = (x_1 \cdot w_{12}) \cdot (x_2 \cdot w_{24}) \cdot (x_4 \cdot w_{45})$$

$$I_7 = (x_1 \cdot w_{13}) \cdot (x_3 \cdot w_{34}) \cdot (x_4 \cdot w_{45})$$

$$I_8 = (x_1 \cdot w_{12}) \cdot (x_2 \cdot w_{23}) \cdot (x_3 \cdot w_{34}) \cdot (x_4 \cdot w_{45})$$

$$T = I_1 + I_2 + \max\{I_3; I_4\} + \max\{I_5; I_6; I_7; I_8\}$$

For all possible cases with which smokers are associated, we can estimate the direct, indirect and total impacts of v_1 at W_{2-5} on v_5 at W_{3-6} along the above eight directed paths.

Table 6 provides detailed information about direct and indirect impact of v_1 at W_{2-5} on v_5 at W_{3-6} along three most effective directed paths $\rho_1 = (v_1, v_5)$, $\rho_3 = (v_1, v_3, v_5)$, $\rho_5 = (v_1, v_4, v_5)$.

Table 7 provides detailed information about total impacts of v_1 at W_{2-5} on v_5 at W_{3-6} along the above eight directed paths; percentage of smokers who are associated with each case; and the rate of make a quit attempt for each case.

5. Main research findings

As discussed in Hammond et al. (2007), the effect of health warnings can be measured in various ways. The main methods include “measures of salience, such as noticing and reading the warnings”; “changes in health knowledge and perceptions of risk”; “intentions/motivation to quit”; and “behavioural changes, such as changes in consumption, attempts to quit, and successful cessation”. In this section, we follow the four methods above to identify and discuss the main research findings from four different viewpoints.

5.1. Basic statistics of salience, avoidance, cognitive, forging and make a quit attempt

From Table 2 we can see that, before the larger warning labels were implemented in 2006 between W_4 and W_5 , the percentages of smokers who responded “*never or rarely*” to *salience* were 42.9%, 40.4% and 38%, respectively. The percentages of smokers who took actions to avoid warning labels (*avoidance*) were 12.1%, 4.9% and 4%, respectively. The percentages of smokers who responded “*not at all or a little*” to *cognitive* were 50.4%, 50.3% and 49.9%, respectively. The percentages of smokers who believe warning labels

prevented them from smoking when they were about to (*forgoing*) were 8.8%, 9.8% and 9.9%, respectively. However, after the larger warning labels were implemented, the percentages of smokers who responded “*never or rarely*” to *salience* dropped to 17.5%. The percentages of smokers who took actions to avoid warning labels (*avoidance*) increased to 25.4%. The percentages of smokers who responded “*not at all or a little*” to *cognitive* dropped to 33%. The percentages of smokers who believe warning labels prevented them from smoking when they were about to (*forgoing*) increased to 16%.

At the same time, before the larger warning labels were implemented, the percentages of smokers who responded “*often or very often*” to *salience* were 23.7%, 24.4% and 23.5%, respectively. The percentages of smokers who responded “*a lot*” to *cognitive* were 16.5%, 16% and 14.5%, respectively. However, after the larger warning labels were implemented, the percentages of smokers who responded “*often or very often*” to *salience* increased to 45.3%. The percentages of smokers who responded “*a lot*” to *cognitive* increased to 29.8%.

There was no obvious difference in the percentages of smokers who responded “*sometimes*” to *salience* and responded “*somewhat*” to *cognitive* over the five years. There was no much difference for the rates of *make a quit attempt* over five years.

All the above demonstrated that after the larger warning labels were implemented, smokers’ awareness to health warnings and health knowledge, perceptions of risk and intentions/ motivation to quit was increased obviously. However, there were no obvious changes in attempting to quit. The possible explanation for this was that the rate of *make a quit attempt* was not affected by health warnings only, many other factors, such as addiction to smoking, education level, and personality, can affect the outcomes of attempting to quit.

5.2. Interrelated relationships among salience, avoidance, cognitive, forging and make a quit attempt

From Tables 3–5 we can see that over the five years, when smokers’ response to *salience* changed from “*never or rarely*” to “*often or very often*”, the percentage of smokers who took actions to avoid warning labels (*avoidance*) increased from 8.8%, 8.6%, 6.3%, 29.6% to 19.1%, 23.1%, 14.7%, 40.9%, respectively. The percentages of smokers who responded “*not at all or a little*” to *cognitive* dropped from 70.8%, 74.8%, 72%, 69.5% to 26.3%, 25%, 27%, 14.6%, respectively. The percentages of smokers who responded “*a lot*” to *cognitive* increased from 4.3%, 1.8%, 2.3%, 5.1% to 36.4%, 38.6%, 36.1%, 48%, respectively. The percentages of smokers who believe warning labels prevented them from smoking when they were about to (*forging*) increased from 1.8%, 1.3%, 2.3%, 0.4% to 21.4%, 24.8%, 22%, 38%, respectively. The rate of *make a quit attempt* increased from 41.1%, 39.3%, 42.5%, 31.8% to 43.2%, 50.8%, 47%, 45.8%, respectively.

When smokers’ response to *avoidance* changed from “*no*” to “*yes*”, the percentages of smokers who responded “*not at all or a little*” to *cognitive* decreased from 53.1%, 53.6%, 52.2%, 38.1% to 30.5%, 30.4%, 28.3%, 23.9%, respectively. The percentages of smokers who responded “*a lot*” to *cognitive* increased from 4.3%, 1.8%, 2.3%, 5.1% to 36.4%, 38.6%, 36.1%, 48%, respectively. The percentages of smokers who believe warning labels prevented them from smoking when they were about to (*forgoing*) increased from 6.2%,

7.4%, 8.2%, 12.1% to 27.3%, 24.6%, 26.7%, 22.9%, respectively. The rate of *make a quit attempt* increased from 42%, 40.7%, 43.6%, 37.1% to 55.9%, 54.6%, 45.8%, 44.9%, respectively.

When smokers' response to *cognitive* changed from “not at all or a little” to “a lot”, the percentages of smokers who believe warning labels prevented them from smoking when they were about to (*forging*) increased from 1%, 1.2%, 1.8%, 0.4% to 36.8%, 37.3%, 36.1%, 38%, respectively.

When smokers' response to *forgoing* changed from “no” to “yes”, the rate of *make a quit attempt* increased from 42.2%, 41.1%, 41.7%, 36.8% to 58.3%, 58.3%, 64%, 56%, respectively.

Based on the definition of causal relationship from one vertex to another one, which is introduced in Section 3.2, we can interpret all the information above as follows. Before and after the larger warning labels were implemented, the changes in smokers' awareness to health warnings always have causal impact on the changes in health knowledge, perceptions of risk, intentions/motivation to quit and rate of *make a quit attempt*. At the same time, the changes in health knowledge has causal impact on the perceptions of risk, intentions/motivation to quit, and the *rate of make a quit attempt*. The changes in the perceptions of risk have causal impact on the changes in intention/motivation to quit and the rate of *make a quit attempt*. The changes in intention/motivation to quit have causal impact on the rate of *make a quit attempt*. Therefore, if the implemented larger warning labels can stimulate smokers to change their responses to *salience* from a lower to a higher level, than the changes in *avoidance*, *cognitive*, *forgoing* will be influenced by the external stimulus and interact each other to affect the rate of *make a quit attempt*.

5.3. Possible relationships between the total effect and the rate of make a quit attempt

From Fig. 1 we can see that, there are eight directed paths from v_1 (at W_{2-5}) to v_5 (at W_{3-6}), which are used to carry out the direct, indirect and total causal effect from *salience* at W_{2-5} to *make a quit attempt* at W_{3-6} . The amount of these direct, indirect and total effects can be measured by formula (3) described in Section 3, which are very dependent on smokers' overall responses to *salience*, *avoidance*, *cognitive* and *forgoing*; as well as the weight of one response on another one.

From Table 7 we can see that, for different case of overall responses with which smokers are associated, the total causal effect of *salience* at W_{2-5} on *make a quit attempt* at W_{3-6} are quite different. When smokers' responses to *salience*, *avoidance*, *cognitive* and *forgoing* changed gradually from “never or rarely, no, not at all or a little, no” to “very often, yes, a lot, yes”, the total causal effect of *salience* at W_{2-5} on *make a quit attempt* at W_{3-6} linearly increase. However, the corresponding rates of *make a quit attempt* for these cases were very fluctuating that did not show a trend with linear increasing.

All the above demonstrated that before and after the larger warning labels were implemented, there was a strong and positive relationship between the total effect of *salience* at W_{2-5} on *make a quit attempt* at W_{3-6} , but that relationship was clearly non-linear.

5.4. Data flow for the psychosocial and quitting behaviours of all smokers over five years

There were three interesting data patterns, which might provide useful information about the psychosocial and quitting behaviours of all smokers over five years. Data patterns (A), (B) and (C) are discussed below.

Data pattern (A) – Before and after the larger warning labels were implemented, there were always many unusual cases with which only a very few smokers were associated and there was no reasonable relationship between the total causal effect and the rate of *make a quit attempt*. For example, for the case (3, 1, 1, 2), with which only 0%, 0.3%, 0.5% and 0% of smokers who are associated. In this case, the total causal effects of *salience* at W_{2-5} on make a quit attempt at W_{3-6} were 0.59, 0.68, 0.68 and 0.68, respectively, which are very similar over five years. However, the corresponding rates of *make a quit attempt* at W_{3-6} were 0%, 100%, 100% and 0%, respectively, which fluctuated sharply between 0% and 100% over five years. This implies that there was no a reasonable relationship between the total causal effect and corresponding rate of *make a quit attempt*. Accordingly, for data pattern (A), even if we can find out a possible relationship between the total causal effect and rate of *make a quit attempt*, that could not provide any reliable information to evaluate the effect of warning labels on influencing smokers' quitting behaviours over five years. As a result, this data pattern can be ignored. In this case study, we defined the case is an unusual case if it satisfies the condition: **min{Column %}over five years = 0%**. Based on this criterion, thirteen cases were selected to data pattern (A). The total percentage of smokers who were associated with data pattern (A) over five years was always very low (2%, 1.3%, 3.1%, and 1.7%, respectively). More details about data pattern (A) are summarised in Table 8.

Data pattern (B) – Before the larger warning labels were implemented, the highest percentages of smokers were associated with the case (1, 1, 1, 1), which were 25%, 23.6% and 24.5%, respectively. The second highest percentages of smokers were associated with the case (2, 1, 2, 1), which were 12.8%, 11.8% and 14.5%, respectively. The third highest percentages of smokers were associated with the case (2, 1, 1, 1), which were 10.4%, 10% and 12.2%, respectively.

The fourth highest percentages of smokers were associated with the case (1, 1, 2, 1), which were 9%, 8.4% and 7.6%, respectively. In total, the percentages of smokers who were associated with the four top cases were 57.2%, 53.8% and 58.8%, respectively. However, after the larger warning labels were implemented, the percentages of smokers who were associated with the four top cases above decreased to 6.3%, 7.8%, 6.9% and 2.4%, respectively. In total, the percentages of smokers who were associated with the four top cases decreased to 23.4%.

This is good news for the purpose of tobacco control. First, these overall responses to *salience*, *avoidance*, *cognitive*, *forgoing* reflected that, before the new warning labels were implemented, more than half smokers had lower awareness in health warnings and health knowledge and lower perceptions of smoking risk. They did not take any actions to avoid the warning labels and rarely reported that health warnings prevented them from having a cigarette when they were about to do so. However, after the new warning labels were implemented, only 23.4% smokers were associated with this low probability of quitting

activity. Second, compared with all 36 cases, for the four top cases in pattern B the corresponding rate of *make a quit attempt* at W_{3-6} , especially at W_6 were almost the same and belonged to the lowest ranges of rate of *make a quit attempt*. We can put five cases more to data pattern (B) since the rate of *make a quit attempt* for these cases were very similar to that for the four top cases. As a result, before and after the new warning labels were implemented, there was a big drop in the total percentage of smokers who are associated with data pattern (B) (71%, 70.9%, 71% and 44.5%, respectively). At the same time, we can work out the lower weighted average for the total causal effort at W_{3-6} and lower weighted average for the rate of *make a quit attempt* at W_{3-6} (0.29, 0.30, 0.30, 0.36 and 40.1%, 39.6%, 40.2%, 30.4%, respectively). More details about data pattern (B) are summarised in Table 9.

Data pattern (C) – The remaining thirteen cases relate to this category. For this data pattern, smokers' psychosocial and quitting behaviours were very complex. First, for the cases (2, 2, 2, 1), (2, 2, 3, 1), (2, 2, 3, 2), (3, 1, 2, 2), (3, 1, 3, 1), (3, 1, 3, 2), (3, 2, 3, 1) and (3, 2, 3, 2), before and after the new warning labels were implemented, there were obvious increases in the percentages of smokers who were associated with each of these cases. In total, before the new warning labels were implemented, the percentages of smokers who were associated with these cases were 16.5%, 18.6% and 16.1%, respectively. However, after the larger warning labels were implemented, the percentages of smokers who were associated with these cases increased to 43.2%. All the information above reflected that, before the new warning labels were implemented, only around one-third smokers had higher awareness in health warnings and health knowledge and higher perceptions of smoking risk. No matter whether they had taken any actions to avoid the warning labels or believe that health warnings prevented them from having a cigarette when they were about to do so. However, after the new warning labels were implemented, for the same responses to *avoidance* and *forgoing*, 43.2% smokers had higher awareness in health warnings (*salience*) and health knowledge and higher perceptions of smoking risk (*cognitive*). Other six more cases were put to data pattern (C) since the rate of *make a quit attempt* for these cases were very similar to that for the eight cases above. Second, the total causal effect that v_5 received at W_{3-6} for smokers who were associated with data pattern (C) were much higher than that for smokers who were associated with data pattern (B). Compared with the rate of *make a quit attempt* for smokers who were associated with data pattern (B), the corresponding rate of *make a quit attempt* for smokers who were associated with data pattern (C) almost doubles. Also after the new warning labels implemented, more smokers were associated with data pattern (C) (increased from 27.1%, 27.8% and 25.5%, respectively, to 53.7%). Therefore, after the new warning labels were implemented, many more smokers switched from the data pattern (B) to data pattern (C) at W_6 . More details about pattern (C) are summarised in Table 10.

6. Conclusions

In this paper, we have explored an application of FCNs to tobacco control policy analysis. We have constructed FCN-based model to monitor and evaluate the effect of warning labels on cigarette packs in influencing Australian smokers' psychosocial and quitting behaviours over five years. The constructed FCN consists of four vertices "*salience*, *avoidance*, *cognitive*, *forgoing*" generated from ten questions selected from W_i and the fifth output vertex "*make a quit attempt*" selected from W_{i+1} of the ITC project. Based on the

constructed FCN and relevant causal inference mechanism, we have examined the relationships among *salience*, *avoidance*, *cognitive*, *foregoing* and *make a quit attempt*; identified the direct, indirect and total effect of *salience* on *make a quit attempt* along eight directed paths from the former to the latter and the possible relationship between the total effect and the rate of make a quit attempt (which is clearly non-linear); identified three interesting data patterns which demonstrate the effect of the new warning labels implemented in Australia in 2006. This case study has indicated that FCN has potential to become a useful framework for causal discovery and decision support in tobacco control systems, especially in the cases where strong interaction among various attributes is involved.

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Fig. 1.
FCN based on four constructed new questions at W_{2-5} and one question at W_{3-6} .

Table 1

Original 10 variables, constructed four input attributes at W_i and one output attribute at W_{i+1} .

Original variables	Associated questions	Response to questions
WL201	How often have you noticed the warning labels on cigarette packages?	1 = never, 2 = sometimes, 3 = very often
WL211	How often have you read or looked closely at the warning labels on cigarette packs?	1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = very often
WL311	Have you made any effort to avoid looking at or thinking about the warning labels covering the warning up?	1 = no, 2 = yes
WL321	Have you made any effort to avoid looking at or thinking about the warning labels keep the pack out of sight?	1 = no, 2 = yes
WL331	Have you made any effort to avoid looking at or thinking about the warning labels using a cigarette case or some other pack?	1 = no, 2 = yes
WL341	Have you made any effort to avoid looking at or thinking about the warning labels buying packs with particular labels?	1 = no, 2 = yes
BQ227	Have the warning labels on cigarette packages led you to thinking about quitting?	1 = not at all, 2 = somewhat, 3 = very much
WL441	Do the warning labels make you think about the health risks of smoking?	1 = not at all, 2 = somewhat, 3 = a lot
WL421	Do the warning labels on cigarette packs make you more likely to quit smoking?	1 = not at all, 2 = somewhat, 3 = a lot
WL221	Have the warning labels stopped you from having a cigarette when you were about smoke one?	1 = never, 2 = once, 3 = a few times, 4 = many times
New input attributes	Method for constructing new Attributes	Responses to new attributes
<i>salience</i>	Visual banding (mean of (WL201, WL211)) by making two equal cutting points	1 = never or rarely, 2 = sometimes, 3 = often or very often
<i>avoidance</i>	Recode (sum of (WL311, WL321, WL331, W341)) to have actions or do not have action	1 = no, 2 = yes
<i>cognition</i>	Visual banding (mean of (BQ227, WL411, WL421)) by making two equal cutting points	1 = not at all or a little bit, 2 = somewhat, 3 = a lot
<i>foregoing</i>	Recoding WL221 to stop or not stop smoking	1 = no, 2 = yes
Output attribute	Associated question	Response to the question
QA331	Have you made any attempts to stop smoking since we last talked with you?	1 = yes, 2 = no

Table 2

Basic statistics for v_1 (*salience*), v_2 (*avoidance*), v_3 (*cognitive*), v_4 (*foregoing*), at W_{2-5} and v_5 (make a *quit attempt*) at W_{3-6} .

Case	Column	% of valid response	Column	% of valid response
v_1	1	42.9	40.4	38
	2	33.3	35.3	38.5
	3	23.7	24.4	23.5
				45.3
v_2	1	87.9	95.1	96
	2	12.1	4.9	4
v_3	1	50.4	50.3	49.9
	2	33.1	33.1	35.6
	3	16.5	16	14.5
				29.8
v_4	1	91.2	90.2	90.1
	2	8.8	9.8	9.9
v_5	1	56.4	57.3	56.1
	2	43.6	42.7	43.9
				40

Table 3

The associations between v_1 (salience), v_2 (avoidance), and v_3 (cognitive) at W_{2-5} .

Case	1	2	3
v_1			
Row % for v_3			
1	70.8	74.8	72
	69.5	24.9	23.3
	25.7	4.3	1.8
	2.3	5.1	
2	41.4	39.7	42.1
	38.2	40.7	43.8
	44.5	42.5	17.9
	16.5	13.4	19.3
3	26.3	25	27
	14.6	37.3	36.4
	36.8	37	36.4
	38.6	36.1	48
v_2			
1	53.1	53.6	52.2
	38.1	33.4	33.6
	35.3	38.3	13.4
	12.7	12.5	23.6
2	30.5	30.4	28.3
	23.9	31.1	33.3
	39.2	35.6	38.4
	36.2	32.5	40.3
v_3			
Row % for v_2			
1	8.8	8.6	6.3
	29.6	91.2	91.4
	93.7	70.4	
2	11.5	14.1	9.7
	34.9	88.5	85.9
	90.3	65.1	
3	19.1	23.1	14.7
	40.9	80.9	76.9
	85.3	59.1	

Table 4

The associations between v_1 (*salience*), v_2 (*avoidance*), v_3 (*cognitive*), and v_4 (*foregoing*), at W_{2-5} as well as between v_1 (*salience*) and v_2 (*avoidance*) at W_{2-5} .

Case	Row % for v_4									
	2					1				
v_1										
1	1.8	1.3	2.3	0.4	98.2	98.7	97.7	99.6		
2	8.6	9	10.1	12.3	91.4	91	89.9	87.7		
3	21.4	24.8	22	38	78.6	75.2	78	62		
v_2										
1	6.2	7.4	8.2	12.1	93.8	92.6	91.8	87.9		
2	27.3	24.6	26.7	22.9	72.7	75.4	73.3	77.1		
v_3										
1	1	1.2	1.8	0.4	99	98.8	98.2	99.6		
2	6.6	9.4	10.7	12.3	93.4	90.6	89.3	87.7		
3	36.8	37.3	36.1	38	63.2	62.7	63.9	62		

Table 5

The associations between v_1 (salience), v_2 (avoidance), v_3 (cognitive), v_4 (foregoing), at W_{2-5} and v_5 (quit attempt) at W_{3-6} .

Case	Row % for v_5							
	2				1			
v_1								
1	41.1	39.3	42.5	31.8	58.9	60.7	57.5	68.2
2	47.2	41.1	43.5	36.8	52.8	58.9	56.5	63.2
3	43.2	50.8	47	45.8	56.8	49.2	53	54.2
v_2								
1	42	40.7	43.6	37.1	58	59.3	56.4	62.9
2	55.9	54.6	45.8	44.9	44.1	45.4	54.2	55.1
v_3								
1	37.6	37	40.5	27.9	62.4	63	59.5	72.1
2	43.3	44.6	42	37.2	56.7	55.4	58	62.8
3	62.9	56.8	60.1	57	37.1	43.2	39.9	43
v_4								
1	42.2	41.1	41.7	36.8	57.8	58.9	58.3	63.2
2	58.3	58.3	64	56	41.7	41.7	36	44

Table 6

Impact of v_1 at W_{3-6} along three most effective directed paths $\{\rho_1, \rho_3, \rho_5\}$ for each case with which smokers are associated.

Case	Impact of v_1 at W_{2-5} on v_5 at W_{3-6} along three most effective direct paths														
	$\rho_1 = (v_1, v_2)$					$\rho_3 = (v_1, v_3, v_5)$					$\rho_5 = (v_1, v_4, v_5)$				
(1, 1, 1, 1)	0.14	0.13	0.14	0.10	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 1, 1, 2)	0.14	0.13	0.14	0.10	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 1, 2, 1)	0.14	0.13	0.14	0.10	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 1, 2, 2)	0.14	0.13	0.14	0.10	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 1, 3, 1)	0.14	0.13	0.14	0.10	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
(1, 1, 3, 2)	0.14	0.13	0.14	0.10	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
(1, 2, 1, 1)	0.14	0.13	0.14	0.10	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 2, 1, 2)	0.14	0.13	0.14	0.10	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 2, 2, 1)	0.14	0.13	0.14	0.10	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 2, 2, 2)	0.14	0.13	0.14	0.10	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(1, 2, 3, 1)	0.14	0.13	0.14	0.10	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
(1, 2, 3, 2)	0.14	0.13	0.14	0.10	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
(2, 1, 1, 1)	0.31	0.27	0.29	0.24	0.03	0.03	0.03	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(2, 1, 1, 2)	0.31	0.27	0.29	0.24	0.03	0.03	0.03	0.04	0.02	0.03	0.03	0.04	0.05	0.05	0.05
(2, 1, 2, 1)	0.31	0.27	0.29	0.24	0.08	0.09	0.08	0.09	0.07	0.00	0.00	0.00	0.00	0.00	0.00
(2, 1, 2, 2)	0.31	0.27	0.29	0.24	0.08	0.09	0.08	0.09	0.07	0.03	0.03	0.04	0.05	0.05	0.05
(2, 1, 3, 1)	0.31	0.27	0.29	0.24	0.07	0.06	0.06	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
(2, 1, 3, 2)	0.31	0.27	0.29	0.24	0.07	0.06	0.06	0.05	0.07	0.03	0.03	0.04	0.05	0.05	0.05
(2, 2, 1, 1)	0.31	0.27	0.29	0.24	0.03	0.03	0.03	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
(2, 2, 1, 2)	0.31	0.27	0.29	0.24	0.03	0.03	0.03	0.04	0.02	0.03	0.03	0.04	0.05	0.05	0.05
(2, 2, 2, 1)	0.31	0.27	0.29	0.24	0.08	0.09	0.08	0.09	0.07	0.00	0.00	0.00	0.00	0.00	0.00
(2, 2, 2, 2)	0.31	0.27	0.29	0.24	0.08	0.09	0.08	0.09	0.07	0.03	0.03	0.04	0.05	0.05	0.05
(2, 2, 3, 1)	0.31	0.27	0.29	0.24	0.07	0.06	0.06	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
(2, 2, 3, 2)	0.31	0.27	0.29	0.24	0.07	0.06	0.06	0.05	0.07	0.03	0.03	0.04	0.05	0.05	0.05
(3, 1, 1, 1)	0.43	0.51	0.51	0.46	0.03	0.03	0.03	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
(3, 1, 1, 2)	0.43	0.51	0.51	0.46	0.03	0.03	0.03	0.04	0.01	0.12	0.14	0.14	0.21	0.21	0.21
(3, 1, 2, 1)	0.43	0.51	0.51	0.46	0.11	0.11	0.11	0.10	0.09	0.00	0.00	0.00	0.00	0.00	0.00

Case	Impact of v_1 at $W_{2,5}$ on v_5 at $W_{3,9}$ along three most effective direct paths											
	$\rho_1 = (v_1, v_2)$			$\rho_2 = (v_1, v_3, v_5)$			$\rho_3 = (v_1, v_4, v_5)$			$\rho_4 = (v_1, v_4, v_5)$		
(3, 1, 2, 2)	0.43	0.51	0.51	0.46	0.11	0.11	0.10	0.09	0.12	0.14	0.14	0.21
(3, 1, 3, 1)	0.43	0.51	0.51	0.46	0.23	0.22	0.22	0.27	0.00	0.00	0.00	0.00
(3, 1, 3, 2)	0.43	0.51	0.51	0.46	0.23	0.22	0.22	0.27	0.12	0.14	0.14	0.21
(3, 2, 1, 1)	0.43	0.51	0.51	0.46	0.03	0.03	0.04	0.01	0.00	0.00	0.00	0.00
(3, 2, 1, 2)	0.43	0.51	0.51	0.46	0.03	0.03	0.04	0.01	0.12	0.14	0.14	0.21
(3, 2, 2, 1)	0.43	0.51	0.51	0.46	0.11	0.11	0.10	0.09	0.00	0.00	0.00	0.00
(3, 2, 2, 2)	0.43	0.51	0.51	0.46	0.11	0.11	0.10	0.09	0.12	0.14	0.14	0.21
(3, 2, 3, 1)	0.43	0.51	0.51	0.46	0.23	0.22	0.22	0.27	0.00	0.00	0.00	0.00
(3, 2, 3, 2)	0.43	0.51	0.51	0.46	0.23	0.22	0.22	0.27	0.12	0.14	0.14	0.21

Table 7

Percentage of smokers, total effects and rate of make a quit attempt at W_{3-6} for 36 cases with which smokers are associated, where “-” represents no smokers are associated with that case.

Case	Column %	Total effect	Row %
(1, 1, 1, 1)	25	23.6	24.5
(1, 1, 1, 2)	0	0	0.2
(1, 1, 2, 1)	9	8.4	7.6
(1, 1, 2, 2)	0.2	0	0.5
(1, 1, 3, 1)	1.4	0.8	0.4
(1, 1, 3, 2)	0.3	0.2	0.5
(1, 2, 1, 1)	2.2	2.1	1.1
(1, 2, 1, 2)	0.2	0	0
(1, 2, 2, 1)	1.3	1.8	1.1
(1, 2, 2, 2)	0.2	0	0.5
(1, 2, 3, 1)	0.8	0.2	0.2
(1, 2, 3, 2)	0	0	0.2
(2, 1, 1, 1)	10.4	10	12
(2, 1, 1, 2)	0.3	0	0.5
(2, 1, 2, 1)	12.8	11.8	14.5
(2, 1, 2, 2)	0.5	1.4	2.5
(2, 1, 3, 1)	4.7	3.2	4.5
(2, 1, 3, 2)	2.1	1.4	0.9
(2, 2, 1, 1)	1.7	1.6	0.9
(2, 2, 1, 2)	0	0	0
(2, 2, 2, 1)	1.3	2.2	1.1
(2, 2, 2, 2)	0	0.3	0.2
(2, 2, 3, 1)	1.1	1.1	0.4
(2, 2, 3, 2)	1.3	0.8	0.5
(3, 1, 1, 1)	3.6	4.9	5.5
(3, 1, 1, 2)	0	0.3	0.5
(3, 1, 2, 1)	5.5	6.7	3.8
(3, 1, 2, 2)	0	0	0
(3, 1, 3, 1)	0	0	0
(3, 1, 3, 2)	0	0	0
(3, 1, 4, 1)	0	0	0
(3, 1, 4, 2)	0	0	0
(3, 1, 5, 1)	0	0	0
(3, 1, 5, 2)	0	0	0
(3, 1, 6, 1)	0	0	0
(3, 1, 6, 2)	0	0	0
(3, 1, 7, 1)	0	0	0
(3, 1, 7, 2)	0	0	0
(3, 1, 8, 1)	0	0	0
(3, 1, 8, 2)	0	0	0
(3, 1, 9, 1)	0	0	0
(3, 1, 9, 2)	0	0	0
(3, 1, 10, 1)	0	0	0
(3, 1, 10, 2)	0	0	0
(3, 1, 11, 1)	0	0	0
(3, 1, 11, 2)	0	0	0
(3, 1, 12, 1)	0	0	0
(3, 1, 12, 2)	0	0	0
(3, 1, 13, 1)	0	0	0
(3, 1, 13, 2)	0	0	0
(3, 1, 14, 1)	0	0	0
(3, 1, 14, 2)	0	0	0
(3, 1, 15, 1)	0	0	0
(3, 1, 15, 2)	0	0	0
(3, 1, 16, 1)	0	0	0
(3, 1, 16, 2)	0	0	0
(3, 1, 17, 1)	0	0	0
(3, 1, 17, 2)	0	0	0
(3, 1, 18, 1)	0	0	0
(3, 1, 18, 2)	0	0	0
(3, 1, 19, 1)	0	0	0
(3, 1, 19, 2)	0	0	0
(3, 1, 20, 1)	0	0	0
(3, 1, 20, 2)	0	0	0
(3, 1, 21, 1)	0	0	0
(3, 1, 21, 2)	0	0	0
(3, 1, 22, 1)	0	0	0
(3, 1, 22, 2)	0	0	0
(3, 1, 23, 1)	0	0	0
(3, 1, 23, 2)	0	0	0
(3, 1, 24, 1)	0	0	0
(3, 1, 24, 2)	0	0	0
(3, 1, 25, 1)	0	0	0
(3, 1, 25, 2)	0	0	0
(3, 1, 26, 1)	0	0	0
(3, 1, 26, 2)	0	0	0
(3, 1, 27, 1)	0	0	0
(3, 1, 27, 2)	0	0	0
(3, 1, 28, 1)	0	0	0
(3, 1, 28, 2)	0	0	0
(3, 1, 29, 1)	0	0	0
(3, 1, 29, 2)	0	0	0
(3, 1, 30, 1)	0	0	0
(3, 1, 30, 2)	0	0	0
(3, 1, 31, 1)	0	0	0
(3, 1, 31, 2)	0	0	0
(3, 1, 32, 1)	0	0	0
(3, 1, 32, 2)	0	0	0
(3, 1, 33, 1)	0	0	0
(3, 1, 33, 2)	0	0	0
(3, 1, 34, 1)	0	0	0
(3, 1, 34, 2)	0	0	0
(3, 1, 35, 1)	0	0	0
(3, 1, 35, 2)	0	0	0
(3, 1, 36, 1)	0	0	0
(3, 1, 36, 2)	0	0	0

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Case	Column %			Total effect				Row %			
(3, 1, 2, 2)	0.8	0.8	1.8	2.1	0.66	0.76	0.75	0.76	55.6	50	58.8
(3, 1, 3, 1)	4.7	4	5.6	9.5	0.66	0.73	0.72	0.73	52.6	50	56.4
(3, 1, 3, 2)	3.2	4.5	3.6	6	0.79	0.87	0.87	0.94	60.6	71.8	76.9
(3, 2, 1, 1)	0	0.8	0.5	1.5	0.57	0.66	0.61	0.66	–	50	60
(3, 2, 1, 2)	0	0.3	0	0	0.70	0.81	0.75	0.87	–	100	–
(3, 2, 2, 1)	0.8	1	0.4	4.1	0.65	0.74	0.68	0.73	29.4	50	18.2
(3, 2, 2, 2)	0.6	0.6	0	2.2	0.77	0.89	0.82	0.95	50	44.4	–
(3, 2, 3, 1)	1.9	2.5	1.1	8.4	0.77	0.85	0.79	0.92	92.3	69.6	75
(3, 2, 3, 2)	2.2	2.7	2	7.3	0.89	1.00	0.93	1.13	60.9	63	68.8
											56.5

Table 8

Percentage of smokers at W_{2-5} , total effect and actual rate of make a quit attempt at W_{3-9} for data pattern (A).

Case	Column %			Total effect			Row %				
(1, 1, 1, 2)	0	0	0.2	0	0.17	0.16	0.18	0.13	-	50	-
(1, 1, 2, 2)	0.2	0	0.5	0	0.16	0.16	0.17	0.13	33.3	-	100
(1, 1, 3, 2)	0.3	0.2	0.5	0	0.15	0.14	0.15	0.12	100	100	-
(1, 2, 1, 2)	0.2	0	0	0	0.19	0.18	0.19	0.18	50	-	-
(1, 2, 2, 2)	0.2	0	0.5	0.2	0.18	0.17	0.18	0.18	50	-	100
(1, 2, 3, 2)	0	0	0	0.2	0.17	0.16	0.16	0.18	-	-	100
(2, 1, 1, 2)	0.3	0	0.5	0	0.38	0.34	0.37	0.31	66.7	-	50
(2, 2, 1, 2)	0	0	0	0	0.42	0.39	0.40	0.41	-	-	-
(2, 2, 2, 2)	0	0.3	0.2	0.7	0.46	0.44	0.44	0.46	-	50	80
(3, 1, 1, 2)	0	0.3	0.5	0	0.59	0.68	0.68	0.68	-	100	-
(3, 2, 1, 2)	0	0.3	0	0	0.70	0.81	0.75	0.87	-	100	-
(3, 2, 1, 1)	0	0.8	0.5	1.5	0.57	0.66	0.61	0.66	-	50	60
(3, 2, 2, 2)	0.6	0.6	0	2.2	0.77	0.89	0.82	0.95	50	44.4	-
Total	2	1.3	3.1	1.7							

Table 9

Percentage of smokers at W_{2-5} , total effect and actual rate of make a quit attempt at W_{3-9} for data pattern (B).

Case	Column %			Total effect			Row %					
(1, 1, 1, 1)	25	23.6	24.5	6.3	0.16	0.16	0.17	0.13	38.3	35.9	41.4	27.4
(2, 1, 2, 1)	12.8	11.8	14.5	7.8	0.39	0.36	0.37	0.31	46.3	42.3	44.9	31.6
(2, 1, 1, 1)	10.4	10	12	6.9	0.35	0.30	0.32	0.27	37.7	34.1	36.6	27.4
(1, 1, 2, 1)	9	8.4	7.6	2.4	0.16	0.15	0.16	0.13	41.6	45.3	40	38.2
(3, 1, 2, 1)	5.5	6.7	3.8	7.1	0.54	0.62	0.61	0.55	37.2	42	26.9	31.4
(3, 1, 1, 1)	3.6	4.9	5.5	3.9	0.46	0.54	0.54	0.47	27.1	41.3	42.3	32.8
(1, 2, 1, 1)	2.2	2.1	1.1	1.3	0.18	0.18	0.18	0.17	53.8	41.9	42.9	17.9
(2, 2, 1, 1)	1.7	1.6	0.9	3.2	0.39	0.35	0.35	0.37	52.4	52.6	33.3	31.5
(3, 2, 2, 1)	0.8	1	0.4	4.1	0.65	0.74	0.68	0.73	29.4	50	18.2	32.4
Total	71	70.9	71	44.5								
Weight average					0.29	0.3	0.3	0.36	40.1	39.6	40.2	30.4
Weight average – Max					-0.36	-0.45	-0.38	-0.37	-13.7	-13	-4.7	-7.8
Weight average – Min					0.13	0.14	0.13	0.23	13	5.5	22	12.5

Table 10

Percentage of smokers at W_{2-5} , total effect and actual rate of make a quit attempt at W_{3-9} for data pattern (C).

Case	Column %			Total effect			Row %					
(1, 1, 3, 1)	1.4	0.8	0.4	0.7	0.14	0.13	0.11	64.3	71.4	28.6	100	
(1, 2, 2, 1)	1.3	1.8	1.1	1.7	0.18	0.17	0.17	57.1	68.8	50	40.9	
(1, 2, 3, 1)	0.8	0.2	0.2	0.6	0.16	0.15	0.17	55.6	33.3	100	75	
(2, 1, 2, 2)	0.5	1.4	2.5	1.3	0.42	0.39	0.41	33.3	47.4	70	53.8	
(2, 1, 3, 1)	4.7	3.2	4.5	3.9	0.39	0.33	0.34	63.8	39.2	65.8	53.8	
(2, 1, 3, 2)	2.1	1.4	0.9	0.7	0.42	0.37	0.38	68.4	69.2	38.5	80	
(2, 2, 2, 1)	1.3	2.2	1.1	5.2	0.43	0.41	0.4	61.5	50	37.5	44.4	
(2, 2, 3, 1)	1.1	1.1	0.4	2.8	0.43	0.38	0.37	63.6	50	33.3	44.1	
(2, 2, 3, 2)	1.3	0.8	0.5	1.9	0.46	0.42	0.41	80	62.5	37.5	52.6	
(3, 1, 2, 2)	0.8	0.8	1.8	2.1	0.66	0.76	0.75	55.6	50	58.8	45.8	
(3, 1, 3, 1)	4.7	4	5.6	9.5	0.66	0.73	0.72	52.6	50	56.4	54.3	
(3, 1, 3, 2)	3.2	4.5	3.6	6	0.79	0.87	0.94	60.6	71.8	76.9	55.2	
(3, 2, 3, 1)	1.9	2.5	1.1	8.4	0.77	0.85	0.92	92.3	69.6	75	63.4	
(3, 2, 3, 2)	2.2	2.7	2	7.3	0.89	1	0.93	60.9	63	68.8	56.5	
Total	27.1	27.8	25.5	53.7								
Weight average					0.54	0.6	0.59	0.71	62.9	58.4	61.7	55
Weight average – Max					–0.35	–0.4	–0.34	–0.42	–29.4	–13.4	–38.3	–45
Weight average – Min					0.39	0.47	0.45	0.59	29.6	25.1	33.1	14.1