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**Title Page**

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Dental flossing and automaticity: a longitudinal moderated mediation analysis

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### **Abstract**

We investigated the role of behavioural automaticity and action control in predicting dental flossing behaviour. Between May and October 2015, 629 Australian young adults completed a questionnaire assessing constructs of normative support and automaticity, and a 2-week follow-up of dental flossing behaviour and action control, resulting in  $n=241$  persons for longitudinal analysis. Findings supported the hypotheses that the effect of normative support on behaviour would be mediated via automaticity, and the effect of automaticity would be moderated by action control. Current results extend previous research to elucidate the mechanisms that help to understand predictors of oral hygiene behaviours and contribute to the cumulative evidence concerning self-regulatory and automatic components of health behaviour.

## Introduction

Although recent reports have indicated there is insufficient evidence to support dental flossing (e.g., Wilder & Bray, 2016), daily flossing is still recommended by leading dental authorities (American Dental Association, 2016; Australian Dental Association, 2017). Despite this, a large proportion of people floss less than the recommended frequency or not at all, including young adults (Chan & Chin, 2017; Crabtree, Kirk, Moore & Abraham 2016; Schüz, Sniehotta, Wiedemann & Semann, 2006; Schwarzer, Antoniuk & Gholami, 2015), indicating more work is needed in this area (Scheerman et al., 2016).

Emerging research has started to investigate the role of self-regulatory (Lhakhang et al., 2016; Zhou, Sun, Knoll, Hamilton & Schwarzer, 2015) and automatic (Judah, Gardner & Aunge, 2013) factors on oral hygiene behaviours. Regarding the latter, automatic action refers to a process by which, as a consequence of repeated action in stable contexts, learned cue-response associations are formed so that cues automatically trigger behaviour. Thus, behaviours that have become automatic require minimal mental effort to perform because it is not necessary to consciously remind oneself to act (Gardner, 2015).

For behaviour to become automatic, first, the action originates in a decision to act, and subsequently, as a result of frequent repetition, acquires the characteristics of automaticity over time. In deciding to act, research has shown that individuals are more motivated when there is perceived normative support from significant others' own attitudes and behaviours in the domain (Rivis & Sheeran, 2003; Robinson, White & Hamilton, 2013; White, O'Connor & Hamilton, 2011). Observing relevant others' actions provides salient information about the normal way to behave - if others important to me floss, it must be a good thing to do. Young adulthood is a period associated with heightened sensitivity to social influences as well as affording the greatest contact with family and peers (Hamilton, Warner & Schwarzer, 2017; Rivis & Sheeran, 2003). In this context, it may be that among young adults, given the importance of relying on observations of what relevant others do as a guide to behavioural action, dental flossing is initially carried out based on these

observations (regardless of whether these observations are accurate or misconceptions; Prentice & Miller, 1993) but eventually becomes automatic.

Action control has also been identified as important to behavioural action. Action control is a self-regulatory strategy that comprises monitoring one's progress, comparing performance with goals, and investing more effort if needed. Prior research has shown support for the role of action control in improving oral hygiene behaviours (Schüz, Sniehotta & Schwarzer, 2007; Schwarzer et al., 2015), with a recent systematic review finding goal setting, self-monitoring, and planning to be effective behaviour change strategies for improving oral hygiene-related behaviours in patients with periodontal disease (Newton & Asimakopoulou, 2015). Action control appears to be essential in the adoption and early maintenance of health behaviour. Later on, when the behaviour becomes automatic, action control diminishes and is replaced by automaticity. Thus, action control and automaticity represent two sequential processes in the course of behaviour change, the latter one being proof of successful adoption. Automaticity makes action control redundant. It is suggested that automatic actions persist even when self-regulatory resources, such as action control, are depleted (Gardner, 2015; Neal, Wood, & Drolet, 2013). Action control should therefore become less predictive of behaviour as automaticity strength increases, so that, where action control is weak and automaticity is strong, behaviour corresponds with automaticity and not action control.

We investigated the role of behavioural automaticity and action control in predicting dental flossing behaviour. In line with the theoretical propositions discussed above, it was hypothesised that the effect of normative support on behaviour would be mediated via automaticity and that the effect of automaticity on behaviour would be moderated by action control. Both assumptions are integrated in a moderated mediation model.

## **Method**

### **Participants and Procedure**

Participants ( $N = 629$ ; women (78.2%,  $n = 485$ ), men (21.8%,  $n = 135$ ) (9 missing);  $M_{age} = 21.21$ ,  $SD = 4.88$ ) were young adults recruited from a major university in Queensland, Australia.

Ethical approval was granted by the university Human Research Ethics Committee. Data were collected over a five-month period between May and October 2015. Participants completed a baseline paper-based questionnaire assessing normative support, automaticity, and past behaviour. Two weeks later, participants completed a phone follow-up assessing dental flossing behaviour and action control. An information sheet outlining the details of the study was provided to all participants and informed consent was assumed by completion of the survey.

### **Measures**

Full details of measures are presented in Table 1. Three items measured dental flossing behaviour. As the three items did not have the same metric they could not be averaged to a sum score; thus, a single factor analysis over the three items was performed for each assessment point in time, and the factor scores (z values with a mean of 0 and SD of 1.00) were taken for the computation of descriptive results as reported in Table 2 and for the manifest variable regression analyses. Normative support was measured by three items that reflected the behaviours of significant others in this context (Terry and Hogg, 1996). The Self-Report Behavioural Automaticity Index (SRBAI; Gardner, Abraham, Lally & De Bruijn, 2012) was used to measure dental flossing automaticity. Action control was measured by three items that reflected participants' self-monitoring, perceived effort, and recalling their intentions of their dental flossing behaviour.

### **Analytic Procedures**

Computations were performed using the SPSS Process macro by Hayes (2013). Simple mediation, moderated mediation, and simple slope analyses were performed. To examine the moderated mediation hypothesis, a model was specified in which behavioural automaticity was a putative mediator between normative support and flossing at follow-up whereas flossing was regressed on normative support, automaticity, action control, and the interaction between automaticity and action control, using baseline flossing as a covariate. Confidence intervals (95%) were generated by bootstrapping with 5,000 re-samples.

### **Results**

Means, standard deviations, and intercorrelations are shown in Table 2. Using listwise deletion of missing values, out of a total  $N=629$  participants who completed the baseline assessment,  $n=241$  participant data were available for the longitudinal analysis. To examine attrition bias, a multivariate analysis of variance was computed with all baseline study variables as dependent variables and a drop-out code as fixed factor (Wilk's lambda=.96,  $F_{(5,577)}=4.8$ ,  $p<.01$ ). The only significant difference was on age (returning:  $M=22.23$  years,  $SD=6.40$ , dropped out:  $M=20.53$  years,  $SD=3.34$ ;  $t_{626} = 4.33$ ,  $p<.01$ ).

### **Moderated Mediation Analysis**

A preliminary simple mediation analysis involving normative support, automaticity, and follow-up flossing (controlling for baseline) yielded a significant indirect effect of 0.05 ( $se=.03$ ) CI 95% [0.007, 0.115]. After mediation was established, the moderated mediation model was specified, yielding a significant index of moderated mediation of -0.05 ( $se=.02$ ) CI 95% [-0.104, -0.014]. The following unstandardized parameters were estimated. The effect of normative support on automaticity was  $b=0.50$ , 95% CI [0.35, 0.65], the effect of automaticity on follow-up flossing was  $b=0.25$ , 95% CI [0.13, 0.37], the effect of action control on follow-up flossing was  $b=0.40$  95% CI [0.34, 0.46], whereas the effect of normative support on follow-up flossing was not significant, and baseline flossing on follow-up flossing was  $b=0.27$ , 95% CI [0.16, 0.39]. The significant interaction between automaticity and action control was  $b=-0.04$ , 95% CI [-0.06, -0.02]. Of the follow-up flossing variance, 77% were accounted for by this joint set of predictors. Controlling for age and sex did not change these results.

To illustrate the moderator effect, a simple slope analysis was performed. Figure 2 demonstrates an ordinal interaction between automaticity and action control on follow-up flossing, controlling for baseline flossing. The subgroup with the lowest action control (1 SD below the mean,  $\beta=.12$ , 95% CI [.04, .26]) had the steepest slope which means that there is a close association between automaticity level and flossing. Similarly, the middle group,  $\beta=.07$ , 95% CI [.01, .16] had a significant slope. In contrast, the subgroup with the highest level of action control (1 SD above the

mean,  $\beta=.02$ , 95% CI [-.04, .07]) had high flossing levels, independent of their automaticity.

Automaticity makes a difference for flossing if action control is low, but also if action control is medium. For individuals who lack action control over their flossing behaviour, having a flossing automaticity is important in actioning behaviour.

### **Discussion**

The aim of the current study was to investigate the role of behavioural automaticity and action control in predicting dental flossing behaviour. Current findings showed that normative support in the form of relevant others' own behavioural performance (e.g., perceiving friends use dental floss) may be an important determinant of the acquisition of a flossing automaticity. The effect of normative support on flossing behaviour was mediated by automaticity. This finding is consistent with evidence showing that young adults in particular are sensitive to social influence in deciding how to act (Rivis & Sheeran, 2003). It is also possible that these social perceptions may come to serve as direct cues to automatic action (Pimm et al., 2016). Current results also provided evidence for a key theoretical prediction regarding the interplay of conscious and nonconscious regulation of health behaviour. Automaticity is useful because it enables behaviour to persist even when self-regulatory resources are depleted (Neal et al., 2011) or self-regulatory effort is low. In line with this proposition, we showed that under conditions of low and medium action control automaticity strength was a key determinant of dental flossing. Development of a strong automaticity serves to protect the behaviour from lapses in action control that might occur when distracted, tired, or under stress for example. In individuals with high action control, automaticity is not needed for successful performance as they consciously monitor their behaviour. The moderated mediation in the current study reflects a compensatory effect of automaticity and action control: either one or the other is sufficient to facilitate dental flossing. Moreover, the established model describes the conditional indirect effect of normative support on the outcome: the mechanism through which normative support exerts its effect on flossing is dependent on the value of action control. Simultaneous examination of both conscious and nonconscious processes (see Strack &



Deutsch, 2004) on dental hygiene behaviour, indeed health behaviour in general, is therefore an important line of investigation that future research should embrace (Arnautovska, Fleig, O’Callaghan & Hamilton, 2017; Hamilton, Kirkpatrick, Rebar & Hagger, 2017; Hagger, Trost, Keech, Chan & Hamilton, 2017; Kremers et al., 2006; Mullan et al., 2016).

Current findings indicate that interventions to promote dental flossing might effectively include elements of action control, by instructing participants to engage in behavioural monitoring for example (Schwarzer et al., 2015). An alternative approach might employ planning interventions to promote the repetition of flossing in a particular location and at a particular time of day, preferably immediately following an existing routine act. Such an approach might rapidly automatize flossing (Hagger & Luszczynska, 2015; Kwasnicka, Pesseau, White, & Sniehotta, 2013; Orbell & Verplanken, 2010; Verplanken & Orbell, 2003), an area for future research.

The results of the current study need to be interpreted in light of study limitations including demand characteristics due to self-reporting and recall bias due to retrospective assessment of behaviour. Objective measures of behaviour may prove more useful (Orbell & Verplanken, 2010; Schüz et al., 2007). Further, the majority female sample and 40% attrition rate limits generalizability of findings, although only differences in age were observed between completers and drop-outs. Finally, while mediation analysis makes causal assumptions, in the current study causality cannot be proven; thus, causal interpretations should be made carefully. Overall, the current study extends previous research to further elucidate the self-regulatory and automatic mechanisms that govern oral hygiene behaviour.

Conflicts of interest: none.

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1 *Table 1. Dental Flossing Among Young Adults (N = 629): Items for Normative Support, Behavioural Automaticity, Action Control, Past*  
 2 *Behaviour and Follow-up Behaviour. Data were collected over a five-month period between May and October 2015.*  
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Variable	Item	Scoring or Rating	Scale Detail and Reliability
Normative Support	In regards to flossing your teeth on a daily basis, do you agree that...		Scores were summed and averaged Cronbach's Alpha = .76.
	My friends use dental floss.	[1] <i>strongly disagree</i> to [7] <i>strongly agree</i>	
	My family use dental floss. Most people like me floss.	[1] <i>strongly disagree</i> to [7] <i>strongly agree</i> [1] <i>strongly disagree</i> to [7] <i>strongly agree</i>	
Action Control	I have consistently monitored when, how often, and how to floss my teeth.	[1] <i>not at all true</i> to [7] <i>definitely true</i>	Scores were summed and averaged. Cronbach's Alpha = .89
	I have often had my dental flossing intentions on my mind.	[1] <i>not at all true</i> to [7] <i>definitely true</i>	
	I have really tried hard to floss my teeth frequently.	[1] <i>not at all true</i> to [7] <i>definitely true</i>	
Behavioural automaticity	Do you agree that flossing is something...		Scores were summed and averaged Cronbach's Alpha = .98
	I do automatically.	[1] <i>strongly disagree</i> to [7] <i>strongly agree</i>	
	I do without having to consciously remember.	[1] <i>strongly disagree</i> to [7] <i>strongly agree</i>	
	I do without thinking. I start doing before I realise I'm doing it.	[1] <i>strongly disagree</i> to [7] <i>strongly agree</i> [1] <i>strongly disagree</i> to [7] <i>strongly agree</i>	
Past and Follow-up Behaviour	Think about the past week. In general, how often did you floss?	[1] <i>never</i> to [7] <i>always</i>	A single factor analysis over the three items was performed for each assessment point in time; factor scores (z values with a mean of 0 and SD of 1.00
	Think about the past week. To what extent did you floss?	[1] <i>not at all</i> to [7] <i>a large extent</i>	
	Think about the entire past week and count, how many times did you floss ___?		

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10 *Table 2.* Descriptive analysis: means (*M*), standard deviations (*SD*), and bivariate correlations for dental flossing among young adults (*n* = 241)  
 11 residing in Queensland, Australia. Data were collected over a five-month period between May and October 2015.

	<i>M</i>	<i>SD</i>	2.	3.	4.	5.	6.	7
1. Sex (80% women, 20% men)			-.09	.14*	.15*	.14*	.15**	.12
2. Age (years)	22.31	6.54	-	.14*	.09	-.02	.15**	.06
3. Flossing baseline <sup>a</sup>	0	1.00			.68**	.41**	.81**	.52**
4. Flossing follow-up <sup>a</sup>	0	1.00				.44**	.62**	.81**
5. Normative support baseline	3.69	1.35				.	.40**	.41**
6. Automaticity baseline	2.35	1.69						.48**
7. Action control follow-up	3.66	1.92						

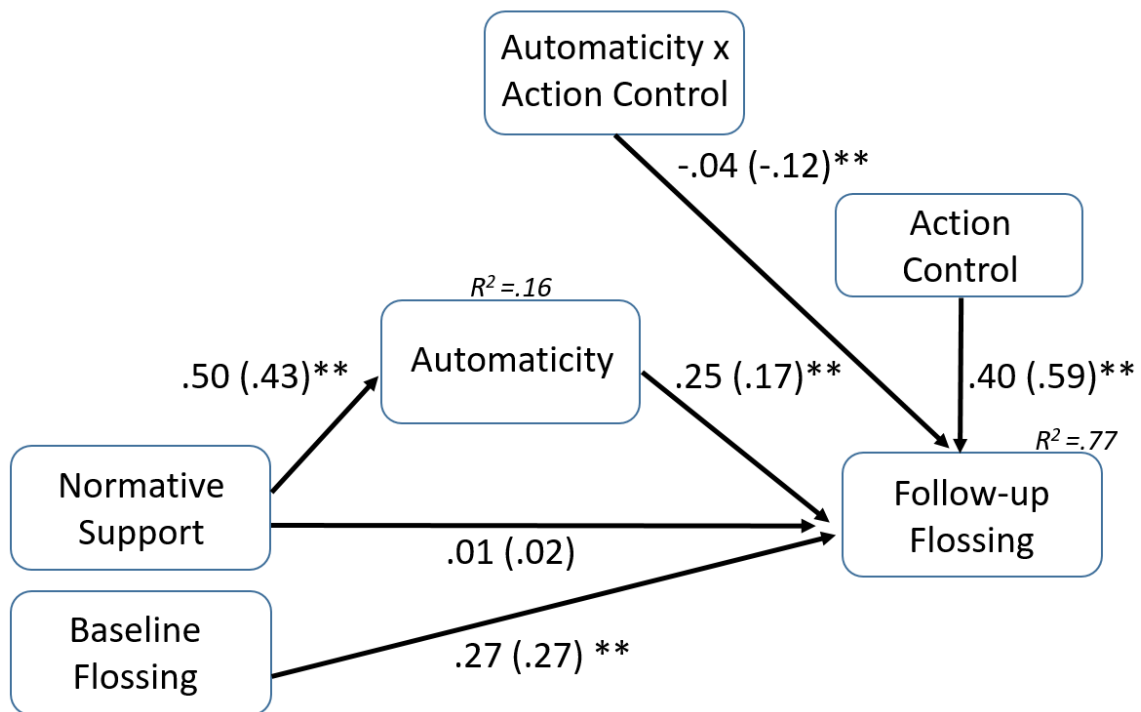
12

13 Note: \**p* < .05; \*\**p* < .01; \*\*\**p* < .001; sex: women=0, men=1;

14 <sup>a</sup> = standard values (*z*) based on factor scores (mean=0; SD=1)

15

16 *Figure 1. Moderated mediation model with unstandardized parameter estimates*  
 17 (standardized coefficients in parentheses): automaticity mediates between normative  
 18 support at baseline and dental flossing behaviour at follow-up, controlling for baseline  
 19 behaviour, and action control moderates the automaticity-flossing relationship. Data  
 20 based on  $n = 241$  young adults residing in Queensland, Australia, over a five-month  
 21 period between May and October 2015.  
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24

25 Note: \* $p < .05$ , \*\* $p < .01$

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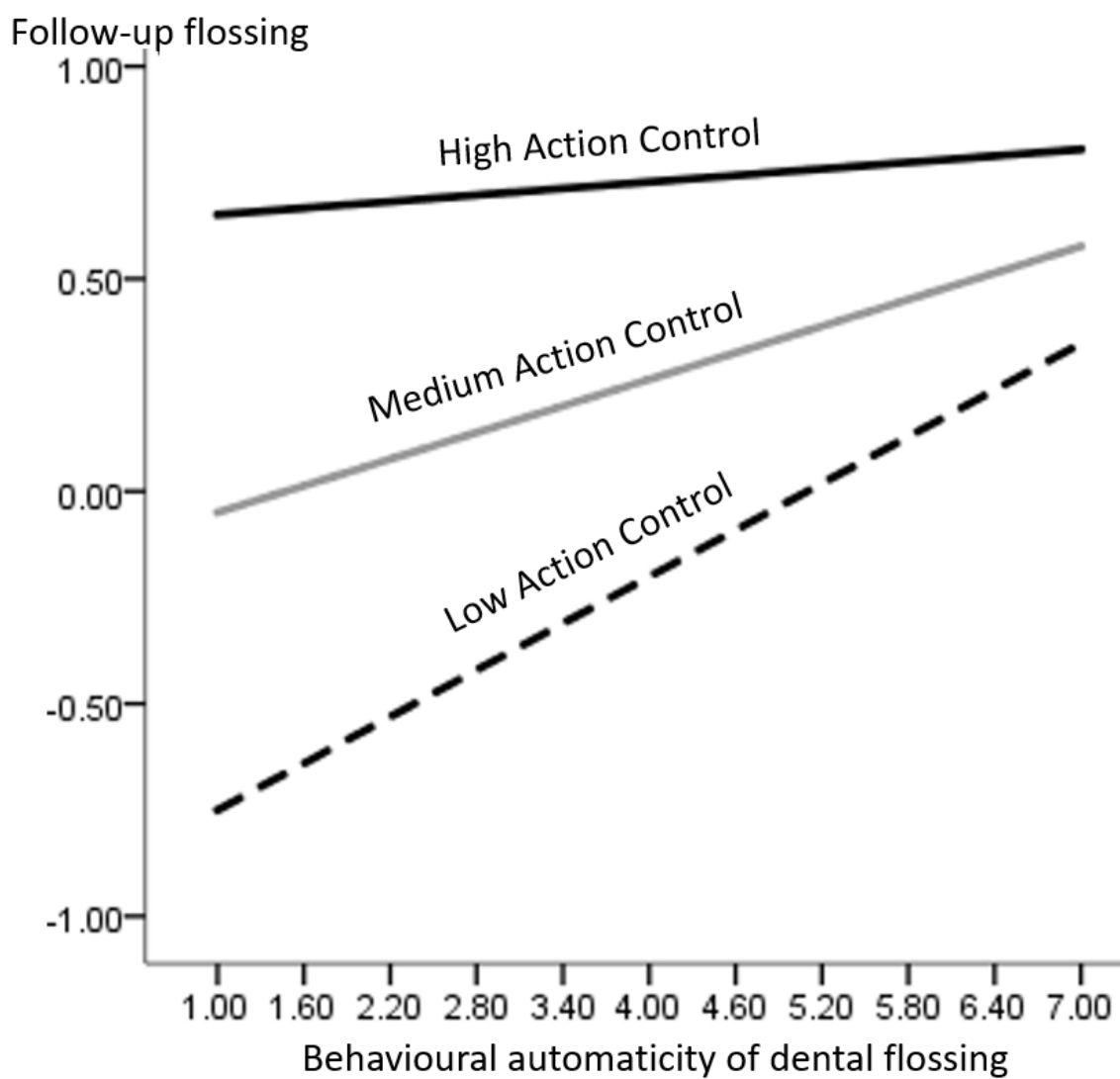
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29 *Figure 2: Simple slope design to show how action control moderates the automaticity-*  
30 *flossing relationship, controlling for baseline dental flossing. Data based on  $n = 241$*   
31 *young adults residing in Queensland, Australia, over a five-month period between May*  
32 *and October 2015. Flossing measure based on factor scores (mean=0; SD=1).*

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