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Perceived importance of facilitators to cycling: the case of a starter cycling city in Italy

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Abstract

The goal of this study is to understand and explore how facilitators to cycling are perceived by different segments of individuals, in view of assessing how to best promote the use of the bicycle in urban areas bicycle-unfriendly. The data for this study is drawn from a survey conducted in the metropolitan area of Cagliari, a starter cycling city in Italy, in 2014-2016 among a sample of local employees. The sample comprises 1,481 observations. All participants were asked to rate, by means of a 5-point Likert Scale, the importance of eight different specified factors that would encourage them to start cycling or to cycle more often. These factors, which are the dependent variables of our study, are modelled jointly using a multivariate ordered probit framework. Our results clearly indicates that how people perceive the implementation of policy measures aimed to encourage more frequent cycling depends on their socio-demographic characteristics. Hence, a holistic approach with a variety of activities is needed, as improvements in cycling infrastructure may not be enough.

Keywords: cycling mobility, starter cycling city, multivariate ordered probit, unobserved effects

1. Introduction

Awareness of the role of sustainable mobility with regard to climate goals and liveability has been constantly growing. Bike-friendly cities and attention to active mobility have been thriving in Italy as well. Nevertheless, good practices have been developed in an uneven way, only in some municipalities or in some relevant geographical areas. In fact, only in some areas in the north of Italy, possibly because of the presence of a greater extension of cycling infrastructure, the daily use of the bicycle as a means of transport is in line with the European average (8%),

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while, throughout the whole Italian territory the bicycle is chosen only by 3.6% of the population (Legambiente, 2018).

Promoting and encouraging bicycle use is certainly worth its value because the use of this active travel alternative does bring not only benefits that have an impact on social health, the environment and the urban space, and more generally the quality of life, but also economic benefits. Indeed, the trips made by bicycle in Italy are able to generate a turnover of around 6 million of euros, which include the sum of the production of bikes and accessories, cycling holidays, and the set of positive externalities generated by cyclists (such as fuel savings, health benefits, or reduction of harmful emissions).

Higher urban densities, the provision of bike facilities, or the presence of bike-sharing services are considered factors that can affect individuals' choice to cycle (Heinen *et al.*, 2010; Handy *et al.*, 2014; Eren and Uz, 2020). However, not all those who have access to these facilities travel by bike, as their behaviour may depend on their individual characteristics or their perception of the built-environment. For instance, while one person may consider the presence of secure bike parking important, another may feel it is relatively safe to park in an open and unsheltered space. Some works argued that this heterogeneity in cycling behaviour could be attributed to the combination of motivational and attitudinal factors that affect in different ways distinct groups of people (Li *et al.*, 2013; Piras *et al.*, 2021). This happens more often in cities with no cycling tradition or technical know-how, the so-called starter cycling cities, where policy makers and practitioners still encounter difficulties implementing measures able to make cycling mobility more appealing and people still have mixed feelings about using the bike for their utilitarian trips.

The literature review on transport research shows that many studies have directed their attention to the physical factors that can influence bike use, other authors investigated cyclists' perceptions, attitudes, intentions, *etc.* (Piras *et al.,* 2021), but few studies explored how different segments of individuals would perceive the implementation of policy measures aimed at encouraging more frequent bike usage. As a matter of fact, the majority of past work research have focused on comparing different infrastructure or routes within the road network (Bhat *et al.*, 2017) or only provided evidence of an association between socio-demographic variables and perception of safety (Aldred *et al.*, 2017; Branion-Calles *et al.*, 2019; Clark *et al.*, 2021). Other studies investigated the propensity to use bike-sharing systems (Eren and Uz, 2020; Torrisi *et al.*, 2021) or to combine the use of the bike with transit (Márquez *et al.*, 2021; Guo *et al.*, 2021) for different cluster of people and specific individuals and household characteristics.

This gap in research generated a lack of knowledge on how people would react to the introduction of measures not related to the perception of safety or the availability of bike-sharing services, with the result that some of them are often implemented indiscriminately at the population level regardless of the individual personality which, on the contrary, represents one of the keys that could open the door of the intention to use the bicycle. Identifying cycling patterns could help to discern which type of cyclists will likely be affected by specific interventions and may support practitioners in developing strategies and interventions in a way that can effectively increase bike use and researchers in gaining a better knowledge of the mechanism underlying the built environment-cycling relationship.

Given the above discussion, we propose a study that aims to understand and explore how facilitators of cycling are perceived by different segments of individuals, in view of assessing how to best promote cycling in an urban area. The data used in this study are derived from a survey conducted in the metropolitan area of Cagliari, a starter cycling in Italy. The methodological approach taken in this study is the construction of a multivariate ordered response model to account for both systematic heterogeneity in the impact of some pro-cycling measures and the presence of possible correlations between unobserved attributes that simultaneously affect different propensities to use the bicycle depending on the action implemented.

The rest of the paper is organized as follows. In the next section we describe the sample characteristics, while in Section 3 we provide an overview of the modelling framework employed for the study. We show model estimation results in Section 4. Key conclusions are provided in Section 6.

2. Data sample

The data for this study is drawn from the survey "Bike I like you" conducted by the University of Cagliari between 2014 and 2016 in the metropolitan cities of Cagliari and Sassari, main cities in Sardinia (Italy). The survey was based on an on-line questionnaire and potential participants were contacted by both mailing lists and through a promotional campaign (see Piras *et al.*, 2021 for more details of the data collection process).

Given the object of the paper we focus only on individuals living and working in the metropolitan area of Cagliari. The final sample comprises 1,481 observations, whose characteristics are reported in Table 1. The sample is almost equally distributed between men (48.3%) and women (51.7%), the average age is 48.26 years, and more than a half of respondents possess a bachelor's degree (57.1%). The majority of the sample have at least one child (54.3%). The average number of cars in the household was equal to 1.74, higher than the average number of bicycles in the household (1.55). 64.1% of respondents fell into the income category 1,001 € – 2,000 €. A vast majority of the households declared to live in an urban area (70.9%). In terms of the use of the bike, 17.1% of the respondents declared to commute by bicycle at least once in the last year, 35.2% reported to cycle for other reasons (shopping/errands, leisure, sport), while 47.7% answered they had not used the bicycle in the last year.

Table 1. Sample characteristics

	N	%	AVG
Total	1,481	100%	
Age			48.26
Age 18-30	63	4.3%	
Age 31-40	211	14.2%	
Age 41-60	1,102	74.4%	
Age >60	105	7.1%	
Gender (male)	716	48.3%	
Bachelor's degree or higher education level	846	57.1%	
Children	804	54.3%	
# of cars in the household			1.74
# of bicycles in the household			1.55
Income			
Income 0.00 € -1,000 €	100	6.8%	
Income 1,001 € – 2,000 €	949	64.1%	
Income 2,001 € – 3,000 €	227	15.3%	
Income > 3,000 €	205	13.8%	
Residence choice (urban)	1,050	70.9%	
Type of cyclist			
Commuter cyclist	253	17.1%	
Other cyclist	521	35.2%	
No cyclist	707	47.7%	

All participants were asked to rate, by means of a 5-point Likert Scale, the importance of specific factors that would encourage them to start cycling or to cycle more often:

- P1. Presence of an extensive network of dedicated bike lanes
- P2. Presence of racks and secure parking for bicycles
- P3. Greater extension of the LTZ (limited traffic zones) or pedestrian zones
- P4. A bike-sharing station close to home or at public transport stops
- P5. If other people cycle
- P6. Dedicated services at work / study (parking, showers, lockers for equipment, etc.)
- P7. Combination with public transport services
- P8. Increase in car parking fees

Responses to these questions constituted the dependent variables in this study, while the regressors are the individual (gender, age, level of education, type of occupation, etc.) and household characteristics (presence of children and number of bicycles) along with some built environment attributes (neighbourhood residence characteristics and presence of bike facilities close to home). Table 2 shows the average values and the distribution of responses to these eight variables. What stands out in the table is that that the majority of individuals would increase their use of the bicycle or take up cycling in the presence of an extensive network of bike lanes and of secure parking for bicycles. Less than a half of the respondents also declared to consider crucial to their decision to cycle the existence of dedicated services at work/study and the combination of cycling facilities with public transport services. Instead, we observed mixed feeling concerning the implementation of measures like an increase in car parking fees or in case other people use bicycle.

Table 2. Average value and distribution of dependent variables

I would cycle more often/ I would start cycling if there were	**AVG**	**Share of responses**				
		1	**2**	**3**	**4**	**5**
The presence of an extensive network of dedicated bike lanes	4.368	3.6%	4.0%	9.0%	18.6%	64.8%
The presence of racks and secure parking for bicycles	4.215	3.6%	5.7%	11.7%	23.6%	55.4%
A greater extension of the LTZ or pedestrian zones	3.693	8.8%	9.9%	21.8%	21.9%	37.5%
A bike-sharing station close to home or at public transport stops	3.656	9.7%	12.0%	18.8%	22.0%	37.5%
If other people cycle	2.934	22.8%	17.8%	22.1%	17.6%	19.6%
A dedicated services at work / study (parking, showers, lockers for equipment, etc.)	3.955	6.1%	7.8%	16.2%	24.2%	45.7%
A combination with public transport services	3.844	7.2%	10.8%	16.3%	21.7%	44.0%
An increase in car parking fees	2.233	43.9%	18.1%	19.2%	8.4%	10.4%

3. Modelling framework

The eight ordinal dependent variables are jointly estimated as common unobserved factors might be present. For this reason, a multivariate ordered probit modelling methodology is adopted in this study.

Let J represent repeated measurements on n different subjects q, where each repeated ordinal observation (indexed by $j \in J$, where $J = 8$ in our study) is denoted by Y_{qj}. Each observable categorical outcome Y_{qj} and the unobservable latent variable $\tilde{Y}_{qj}$ are connected by:

$$Y_{qj} = r_{qj} \Leftrightarrow \vartheta_{j,r_{qj}-1} < \tilde{Y}_{qj} \leq \vartheta_{j,r_{qj}} \qquad r_{qj} \in 1, \dots, K_j \tag{1}$$

where r_{qj} is a category out of K_j ordered categories (in our case $K_j = 5$) and ϑ_j is a vector of threshold parameters for outcome j with the following restriction:

$$-\infty = \vartheta_{j,0} < \vartheta_{j,1} < \cdots < \vartheta_{j,K_j} = \infty \tag{2}$$

The threshold parameters can vary across outcome dimensions $j \in J$ in order to account for differences in the repeated measurements. Given an $n \times p$ matrix X_j of covariates for each $j \in J$, where each x_{qj} is a p-dimensional vector (q-th row of X_j) for subject q and repeated measurement j, the following linear model for the relationship between $\tilde{Y}_{qj}$ and the vector of covariates $\boldsymbol{x}_{qj}$ is assumed:

$$\tilde{Y}_{qj} = \boldsymbol{x}_{qj}^T \boldsymbol{\beta}_j + \varepsilon_{qj}, \quad \varepsilon_q = \left(\varepsilon_{q1}, \varepsilon_{q2}, \dots, \varepsilon_{q8}\right)^T \sim \mathcal{N}(0, \Sigma), \tag{3}$$

where

- $\boldsymbol{\beta}_j$ is a vector of regression coefficients corresponding to outcome j,

- ε_{qj} is an error term with mean zero and multivariate normal distributed with a covariance Σ.

The regression parameters β_j can vary between the repeated measurements j. The errors are assumed to be independent across subjects and orthogonal to the covariates $\boldsymbol{x}_{ij}$. Let the actual observed measurement level for individual q and measurement variable j be m_{qj}. The likelihood function for individual q may be written as follows:

$$LL_q = Pr\left(y_{q1} = m_{q1}, y_{q2} = m_{q2}, \dots, y_{qJ} = m_{qJ}\right) \tag{4}$$

$$LL_q = \int_{v_1=\vartheta_1^{m_{q1}}-\beta_1 x_{q1}}^{\vartheta_1^{m_{q1}+1}-\beta_1 x_{q1}} \int_{v_2=\vartheta_2^{m_{q2}}-\beta_2 x_{q2}}^{\vartheta_2^{m_{q2}+1}-\beta_2 x_{q2}} \dots \int_{v_J=\vartheta_J^{m_{qJ}}-\beta_J x_{qJ}}^{\vartheta_J^{m_{qJ}+1}-\beta_J x_{qJ}} \phi_J\left(v_1, v_2, \dots, v_J | \boldsymbol{R}\right) dv_1 dv_2 \dots dv_J \tag{5}$$

Where ϕ_J in the above expression represents the standard multivariate normal density function and R are the off-diagonal elements of the covariance matrix $\boldsymbol{\Sigma}$. The model parameters were estimated by employing the composite likelihood approach (Varin *et al.*, 2011). All the models were estimated using the R package *mvord* (Hirk *et al.*, 2020).

4. Model results

Different types of variables were considered in the model specification as explanatory factors that influence the perception of various facilitators to cycling. These included individual characteristics, household characteristics and built environment attributes.

Model results are presented in Table 3. The specification of the model was based on a systematic process of removing statistically non-significant variables and combining variables when their effects were not significantly different.

The results indicate the presence of a distinct gender effect. Specifically, females are more likely to place importance on the existence of an extensive network of bike paths and/or of the extension of pedestrian and limited traffic zones. Similarly, it also turned out that the presence of bike racks and secure parking would have a stronger effect among females. All these results support the hypothesis of a large body of academic research that affirms that, on average, females are more concerned with safety issues and tend to avoid risky practices. For the same reason females exhibit a stronger willingness to cycle in the presence of a bike-sharing station close to home or at public transport stops. In this case cycling would limit daily activity patterns to a lesser extent and could help transport inter-modality.

Interestingly, the willingness to cycle significantly differs across age groups for some indicators. In particular, model results pointed out that the presence of a cycle network would have a greater effect in stimulating the use of the bike among youngsters, while for the outcome regarding the presence of facilities at the workplace we found that older respondents value them more highly than the younger individuals.

Highly educated individuals are, in general, less inclined to use the bike. This is in contrast with other studies (e.g. Bhat *et al.*, 2017) that indicate that higher education is linked to increased cycle use. One possible explanation could be that usually university graduates have a more prestigious job, where often a dress code is required, not always compatible with bicycle usage. Furthermore, because of their position, they may be expected to use the car, especially in Italy, where a strong car-centric culture exists, and its ownership is considered as a symbol of social prestige.

Individuals with a lower income are more likely to recognize the importance of the existence of an extensive bike lane network and the presence of bike parking spots. One possible explanation is that this segment of population, due to their fewer financial resources, values safe paths and secure parking much more highly, as the bicycle is a relatively more expensive possession that can be stolen, or damaged due to an accident. We also found that, as the level of income increases, the latent propensity to cycle when other people also cycle decreases.

Table 3. Model results

	P1		*P2*		*P3*		*P4*		*P5*		*P6*		*P7*		*P8*	
	Coeff	*T-stat*	*Coeff*	*T-stat*	*Coeff*	*T-stat*	*Coeff*	*T-stat*	*Coeff*	*T-stat*	*Coeff*	*T-stat*	*Coeff*	*T-stat*	*Coeff*	*T-stat*
Commuter cyclist	0.479	5.30	0.303	3.57	0.383	4.61	-0.260	-3.30	0.224	3.03	0.206	2.56	-0.129	-1.73	--	--
Other cyclist	0.526	7.49	0.357	5.46	0.231	3.72	0.192	3.06	--	--	--	--	--	--	--	--
Male	-0.187	-2.91	-0.278	-4.51	-0.183	-3.13	-0.222	-3.84	-0.151	-2.62	--	--	-0.121	-2.10	--	--
Age	-0.009	-2.79	--	--	--	--	--	--	0.010	2.98	--	--	0.007	2.22	--	--
Bachelor's degree or higher education level	-0.098	-1.52	-0.191	-3.20	--	--	-0.311	-5.37	-0.073	-1.21	-0.127	-2.11	-0.259	-4.14	--	--
Income	-0.091	-2.38	-0.131	-3.58	--	--	-0.106	-2.97	-0.073	-1.92	-0.131	-3.57	-0.141	-3.67		
Presence of children	--	--	--	--	--	--	--	--	--	--	-0.157	-2.80	-0.108	-1.98	-0.101	-1.74
# of cars in the household	--	--	--	--	--	--	0.061	1.69	--	--	--	--	--	--	--	--
# of bicycles in the household	--	--	--	--	--	--	-0.083	-3.25	-0.077	-2.84	--	--	--	--	--	--
Presence of bike lanes within 400m of home	--	--	--	--	--	--	--	--	--	--	--	--	-0.107	-2.01	-0.090	-1.46
Commuting distance	--	--	--	--	-0.008	-1.97	--	--	--	--	-0.013	-2.89	--	--	--	--
Urban	--	--	--	--	-0.168	-2.28	-0.254	-4.25	--	--	-0.384	-4.96	-0.284	-4.38	-0.075	-1.08
Threshold																
Threshold1	-2.418	-12.72	-2.243	-18.95	-1.492	-15.04	-2.136	-17.05	-0.634	-3.49	-2.325	-17.24	-2.054	-12.36	-0.310	-4.50
Threshold2	-2.014	-10.69	-1.724	-15.77	-1.020	-10.65	-1.600	-13.00	-0.126	-0.70	-1.851	-14.04	-1.491	-9.18	0.147	2.14
Threshold3	-1.523	-8.26	-1.196	-11.36	-0.373	-4.02	-1.033	-8.57	0.444	2.45	-1.276	-9.78	-0.966	-6.04	0.730	10.21
Threshold4	-0.919	-5.08	-0.516	-5.04	0.186	2.01	-0.450	-3.81	0.985	5.39	-0.636	-4.98	-0.393	-2.47	1.107	14.95
Correlation terms																
P1	n/a	n/a														
P2	0.831	75.17	n/a	n/a												
P3	0.598	26.91	0.594	28.29	n/a	n/a										
P4	0.535	22.26	0.585	28.27	0.521	25.40	n/a	n/a								
P5	0.249	7.64	0.240	7.82	0.186	6.75	0.312	11.95	n/a	n/a						
P6	0.491	19.26	0.525	22.56	0.373	14.97	0.444	18.90	0.357	13.63	n/a	n/a				
P7	0.484	18.53	0.513	22.40	0.423	17.44	0.681	43.53	0.311	11.48	0.583	30.36	n/a	n/a		
P8	0.113	3.16	0.145	4.26	0.242	8.14	0.268	8.82	0.276	10.29	0.137	4.29	0.242	7.98	n/a	n/a

Goodness of fit measures	*Joint model*	*Independent model*
Log likelihood at convergence	-109,794.16	-112,796.49
Number of parameters	107	79
Adjusted likelihood ratio index	0.041	0.015
Likelihood Ratio Test (LRT) between the Joint and Independent models	χ^2=-2[-112,796.49- (-109,794.16)] = 6,004.66, 28 df, p = 0.000	

Individuals living in a household with a low number of bikes would have a greater incentive to use the bike if other people also did so. This outcome implies that whoever already possesses a bike does not need to see other people cycling to be more inclined to use it. On the other hand, individuals with lower bike access need to be persuaded by other cyclists to use it, suggesting the presence of a social norm component in the decisional process to use the bike. The results also indicate that individuals with no children would have a greater propensity to cycle, were there dedicated facilities at their workplace or an integration with the public transport. Similarly, an increase in car parking fees would not be an incentive to cycle for individuals with children. This is not surprising, given that usually this category of individuals frequently needs to run various errands on the way to or from work and a higher car parking charge might not be sufficient to stimulate the use of the bicycle.

Concerning commuting distance, model results indicated that as commuting distance decreases people's propensity to cycle increases in the case of the introduction of new pedestrian areas and of the installation of dedicated services at work. Instead, the impact of this independent variable turned out to be not significant for all other measures. This may be due to the fact that while measures concerning safety and risk perception like the implementation of new cycle lanes or bike racks are considered important to decide to cycle regardless of the distance, a measure like the presence of dedicated services at work would be a plus only for those individuals who daily face small commuting distances.

Residential location choice is another important determinant. Individuals who live in suburban areas exhibit a greater willingness to cycle when cycling can be combined with public transport, both in terms of presence of bicycle lockers and covered parking facilities or bike sharing services in proximity to public transport stops. This reflect the fact that people living in suburban areas feel that cycling is a non-competitive transport alternative but would consider inter-modality if an integrated service existed. In particular, the implementation of policies supporting the bike-and-ride mode would render the public transport service competitive for those trips with a distance from home to the bus/train stop too long for walking but within a competitive cycling distance. At the same time, we found that are the people living in the suburbs that would benefit the most from the introduction of new pedestrian and limited traffic zones.

Not surprisingly, the results indicate the presence of a distinct effect among commuter cyclists, recreational cyclists and non-cyclists. Specifically, individuals who already use the bike (compared to those who do not) are more likely to place importance on more bicycle lanes and limited traffic zones and the presence of a safe parking spot. This finding is consistent with literature (Namgung and Jun, 2019). Instead, the provision of facilities at workplaces is considered important only for actual commuter cyclists, while they would not benefit from measures aimed at combing the use of the bicycle with public transport services.

Model goodness-of-fit measures are shown in the last block of Table 3. In addition to the joint model, an independent ordered probit model system was estimated by setting all correlation terms to zero. The performance of the joint model was then assessed comparing goodness-of-fit metrics. The value of the adjusted likelihood ratio index for the joint model is slightly higher than that for the independent model, suggesting that the joint model offers a superior goodness-of-fit than the independent model. The χ^2 test statistic of the likelihood ratio test (LRT) between the joint and independent models is statistically significant at any degree of confidence.

All the error correlation terms are significant, suggesting that a multivariate ordered response model that accommodates error correlations is appropriate in this particular context. The error correlation terms indicate the presence of significant unobserved attributes that simultaneously affect the dependent variables considered in the study. For example, it is found that the error correlation for a better bicycle network and the existence of more bike parking spots is positive and significant (0.831 with a t-stat of 75.17). This indicates that unobserved attributes, that contribute to increasing the latent utility of the importance of the presence of an extended bicycle network, are positively correlated with unobserved attributes that contribute to the latent utility of the importance of more safe parking spots.

5. Conclusions

In past research, different authors indicated the existence of heterogeneity in the level of success reached by some pro-cycling actions and strategies, but often they have been focusing only on actions such as the introduction of new bike sharing stations or the construction of new cycle paths, not contemplating other kind of measures like the provision of safe parking spots for bicycles or the presence of dedicated services at workplace, which are pivotal if a public administration desire to make a city more bikeable and wants to guarantee accessibility by bicycle to all. Furthermore, the methodology employed in the past often did not allow to test the effect of combining multiple measures and to which extent unobserved effects, like attitudes and perceptions, influence the different perceived importance of facilitators to cycle. To bridge these gaps, the current study explored, through the construction of a multivariate ordered probit model, whether the impact of the implementation of a set of different measures aimed at encouraging the use of the bicycle differs among different people's categories. The context of our experimentation was the metropolitan city of Cagliari, a starter cycling city in Italy, where a fully connected cycle network does not exist yet, safe parking spaces for bicycles are scarce, people can access to the bike-sharing service only if they live in the city centre and bicycle culture is not mainstream among its inhabitants.

First of all, descriptive analysis of the data revealed that some measures are perceived as more important than others. In particular, it turned out that people's first requirement to use the bike is the construction of a fully-connected network of cycle paths and cycle lanes and the installation of safe parking spaces for bicycles, corroborating results of past research and experiences which suggest that the very first step to make cycling as a reliable travel alternative in car-centric cities is the implementation of infrastructural measures. In light of this, the decision of local governments to dedicate monetary resources for the building of these kind of infrastructures, especially after COVID-19 pandemic, is correct: efforts in promoting cycling only makes sense if good bicycle infrastructure is available.

Another important finding of the paper was that the error terms of the model associated with different dependent variables were correlated with one another. These results indicate that planners and practitioners should design and implement pro-cycling measures that simultaneously make cycling more appealing (holistic approach). For instance, the construction of new cycle lanes and cycle paths should be combined with the introduction of secure parking where individuals can store their bikes, as both measures could reduce concerns about safety and risk perception.

Finally, the results of the model confirmed our hypothesis that different segments of the population might respond differently depending on the measure implemented. In particular, it emerged that individuals who already cycle to work would benefit the most from adoption of measures like the implementation of a safe cycle network or the installation of lockers and changing rooms at the workplace. Does this result implicate that the implementation of infrastructure measures is ineffective for non-cyclists? No, but at the same time in a city where there is not yet a perception of the bicycle as a means of transport, the sole introduction of structural measures may not be sufficient to stimulate people to take up cycling, but these should be combined with behavioural measures, which act on factors such as attitudes, perceptions, emotions, *etc.*

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