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How Can an Alert Entrepreneurial Engineer Recognize Business Opportunities? When the entrepreneurial mental models matter

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***Abstract*—** Every entrepreneurial process starts with opportunity recognition. We know that entrepreneurial alertness makes individuals more prone to discover opportunities. Also, we know that individuals' mental models impact their alertness capability. How does that process occur in engineering students? We made a mixed study to explore the relationship between engineers' opportunity recognition capability, alertness process, and entrepreneurial mental models. We made a self-applied questionnaire. Response options are analyzed quantitatively and later triangulated by a semantic analysis of the item statements. We infer a nonlinear relationship between those entrepreneurial cognitive structures and processes like a virtuous circle. We make theoretical and practical contributions to entrepreneurial cognitive research.

***Index Terms*—** Opportunity Recognition; Alertness; Entrepreneurial Cognition; Mental Model.

I. INTRODUCTION

Currently, firms expect that engineers have knowledge in their field, skills in problem solving, networking, also show creativity, resilience, and risk taking to spot opportunities i.e., an entrepreneurial mindset and skills [1]. So, engineers must exhibit an entrepreneurial mindset to work in a dynamic and creative environment, however there is few research about what factors influence engineering graduates to engage in entrepreneurial behavior [2; 3]. However, engineering education has focused on providing graduates for jobs in established firms ignoring the needs of startups [4].

Entrepreneurial activities are change or rupture drivers achieving higher levels of economic growth, employment, and innovation [5; 6; 7; 8; 9; 10; 11]. Every entrepreneurial process starts with an opportunity discovery [12; 13]. Opportunity can be described as a perceived means to generate an economic value that has not been exploited until now [14].

Individuals' cognition has a central role in recognizing and enacting novel opportunities [15; 16; 17]. Reference [18] argues that entrepreneurial alertness drives the opportunity identification process making individuals more prone to recognize and discover opportunities [19; 20]. However, individuals differ in their cognitive capability of attention so they can differ in how correctly and quickly they sense new opportunities [21].

Selective perception relies on decision rules inside the individuals' mental models which simplify complex competitive environments and allow them to make decisions to filter information [22; 23]. Individuals trapped in a mindset may become prisoners of their assumptions, information filters, and problem-solving strategies for instance preventing a successful opportunity recognition [24; 25]. Attention can trigger changes in a manager's mental model [26; 27].

According to the above, there could be a relationship between the alertness process and mental model structures influencing the individuals' opportunity recognition capabilities. To our knowledge, that relationship has not been studied. The purpose of this work is to explore the relationship between engineering students' and professionals' opportunity recognition capability, alertness process, and entrepreneurial mental models. We used a self-applied questionnaire measuring the respondents' level of opportunity recognition and alertness, and we used mental model proxies such as entrepreneurship education, entrepreneurial knowledge, and entrepreneurial experience antecedent. However, making a quantitative analysis of cross-sectional data could lead to common method bias, risk for spurious results, and potential reverse causality. So, we make a semantic analysis between statements, triangulating the quantitative results to reduce those problems enhancing our understanding of those results.

This study makes two theoretical contributions. First, for entrepreneurial cognitive research, we explore the relationship between individuals' cognitive process (i.e., alertness) and cognitive structures (i.e., entrepreneurial mental model) and their effect on their entrepreneurial skills (i.e., opportunity recognition capability). Second, we make an epistemological contribution to entrepreneurial cognitive literature by using a semantic perspective to explain research results through item statements relationship [28].

This study makes two practical contributions to engineering education. First, it shows that developing an entrepreneurial mindset may require acting on the relationship between cognitive structures and processes to trigger a nonlinear dynamic using non-traditional training methods. Second, it shows that an entrepreneurial mindset requires both entrepreneurship experience and entrepreneurial knowledge at the same time, so firms and education institutions must provide them.

In what follows, first, we explain the pertinent literature and describe the hypothesis. Second, we describe the method. Third, we describe the results. In the fourth section, we discuss the results. Finally, we make conclusions with limitations and future research lines

II. BACKGROUND

A. Opportunity recognition Capability

Opportunity recognition (OR) has been defined as the cognitive process through which individuals infer that they have a business opportunity [14]. Individuals' experiences and

observations may trigger the formation of beliefs about, among others, the opportunities that might be pursued [19]. So, theorizing and imagination play important roles in generating beliefs about new opportunities [19].

Opportunity value can only be determined by post hoc, so opportunity recognition implies subjective efforts to comprehend the environment and imagine what may be [29; 30]. Individuals' mental models acting as templates may enable them to perceive a connection between apparently unrelated environmental changes forming patterns of new business opportunities [14]. So, the centrality of perception in OR argues for taking a cognitive approach in this domain [31].

Individuals can develop through experience or educational background, perceptual capabilities and alertness to recognize opportunities [19]. The ability to recognize business opportunities depends on individuals' experiences, cognitive capabilities, knowledge, and learning capacity [32; 33; 34; 25]. There are at least three factors associated with opportunity recognition: engagement in an active search, alertness, and prior knowledge of a market, industry, or customer [14].

Entrepreneurial education and prior knowledge may positively influence the opportunity recognition in entrepreneurs and undergraduate students [35; 36]. The knowledge gained from prior experiences shapes new perceptions affecting the sensing opportunities [32; 37; 21]. So, in a knowledge-based economy, educational institutions have an important role in enhancing the students' entrepreneurial mindset, especially their OR capabilities [38; 12].

B. Alertness

Alertness is defined as “the state of being awake, aware, attentive, and prepared to act or react". [39]. Attention is an act of focused awareness of specific information that eases the managerial environmental scanning to sense opportunities and threats [21]. Individuals’ alertness makes them more prone to recognize and discover opportunities [19].

People's mental model directs attention to important causal relationships to forecast alternative solutions. Individuals’ mental models about competitors, suppliers, and customers focus their attentional resources on some agents and exclude others [40]. Individuals’ selective perceptions and interpretations are combined to produce the managerial perceptions of a situation [41].

Mental models are used to filter and store new information and can be the basis of individual behaviors [42; 43]. Individuals rely on simplified representations of the world (mental models and strategic beliefs) that direct their attention, therefore higher-quality representations lead to better attention than a misperception of the competitive situation [44; 45].

C. Mental model

Historically [46] suggested that the mind constructs models of reality to anticipate events by reasoning through verbal rules. However, subsequently it has been argued that the reasoning is more a simulation or mental model of the world than a formal manipulation of sentences, so the mental models represent different possibilities, and we based our probabilistic conclusions on them [47; 48; 49].

Individuals have different mental models of industry, market, and firms [40]. Differences depend on their experiences and knowledge [22; 50]. Different mental models have different decision rules to filter the information about market changes [23]. Individuals often use analogical transfer from past experiences to deal with current strategic choices, their ability to apply correct analogies depends on the quality of their perceptions about structural relations in the new problem [20].

When people receive new information they may modify their mental models, however, there is evidence that mental models could be relatively static or resistant to change especially if they are shared [23; 51]. One cause of change in mental models is the detection of inconsistency (i.e., an individual's impasse with their pattern of inference) [43].

D. Hypothesis development

People's mental models can direct attention to important causal relationships. Entrepreneurial alertness is a cognitive process [52; 19; 53] that can be understood as an innate capacity to recognize opportunities [54]. “The alertness component of attention can facilitate the detection and creation of new opportunities” [21, p. 839]. Individuals with greater experience may have greater alertness to opportunities [55].

H1a. Engineering students and professionals with higher levels of alertness have higher levels of opportunity recognition capability than those with lesser levels of alertness.

H1b Engineering students and professionals with higher levels of entrepreneurial knowledge, education, or entrepreneurship experience have higher levels of alertness than those with lesser levels.

Entrepreneurial education may increase opportunity recognition [36] because knowledge and skills influence students’ attention to business [41; 56; 57; 33]. Entrepreneurial knowledge may influence opportunity recognition positively in undergraduate students [36]. Prior experiences shape new perceptions and influence the resemblance between market events and individuals' mental models [37; 32; 29; 21].

H2a. Engineering students and professionals with more entrepreneurial education will show higher opportunity recognition than individuals with less entrepreneurial education.

H2b. Engineering students and professionals with more entrepreneurial knowledge will show higher opportunity recognition than those with less entrepreneurial knowledge.

H2c. Engineering students and professionals with entrepreneurial experiences will show higher opportunity recognition than individuals without that experience.

III. METHOD

This study adopted a mixed design. First, we made a cross-sectional design to gather data from engineering students and professionals with work experiences via a self-applied questionnaire on the Qualtrics™ platform. The response options collected were quantitatively analyzed using SPSS. Second, we triangulated the results by semantic analysis of the related item statements.

A. Sample

The sample encompasses professionals and technicians currently studying engineering as a second profession and engineering post-degree students in a Chilean university. The sample is obtained randomly. They were invited

to answer the survey through university formal authorities in 2023. There is no incentive.

We obtained 473 total responses. We delete all incomplete responses, except if they have a maximum of two numerical items without responses that we replaced with the variable average value. After that cleaning process, 358 responses remained. Respondents were 274 (76.5%) male and 84 (23.5%) female, with an average age of 37.2 years. Their education level included 67 (18.7%) technical, 234 (65.4%) university, and 57 (15.9%) post-degree. They have an average tenure of 6.10 years and 14.74 years of work experience. 42.7% have a functional specialization in operations, 15.4% in IT, 15.9% in administration, 9.5% in logistics, 3.6% in R&D, 4.2% in human resources, 2.2% in finances, 2.5% in accounting, and 3.9% in marketing.

B. Survey

The survey contained demographic (age, gender), educational level (technical, university, post-degree), tenure (years), work experience (years), and functional specialization (marketing, finance, operations, human resources, logistics, research and development, accounting, IT, and administration) questions. Also, we include an entrepreneurship experience (Yes/No) question

C. Variables

We used a Likert scale with five points (strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree). Questions of alertness (AL) are obtained from [53]. They use an AL operational definition with three dimensions: scanning and searching for new information (constantly scanning the environment for changes), connecting previously disconnected information (pulling together pieces of information and building coherent alternatives), and evaluating whether information represents an opportunity (making evaluations and judgment).

Given that the dimension of connection is similar to [21] definition of perception (i.e., the construction of meaningful information from events in the environment through pattern recognition), and the dimension of evaluation is similar to the [21] definition of reasoning and problem-solving capabilities related to seize opportunities, we decided to use only the questions relative to the scanning and searching dimension. So, in this work, AL is operationally defined as self-reported alertness activities.

We use proxies of engineering students and professionals' entrepreneurial mental models such as Entrepreneurship Education (EE), Entrepreneurial Knowledge (EK), and Entrepreneurship Experience. Questions about EE are obtained from [58] and [36]. So, in this work, EE is operationally defined as the opinion about the role of educational institutions in promoting entrepreneurship. Questions of EK are obtained from [59] and [36]. So, in this work, EK is operationally defined as self-reported entrepreneurial knowledge stored. Both scales were selected because their questions were redacted to students. Regarding the Entrepreneurship Experience is measured with a dichotomic item (Yes/No).

Questions of opportunity recognition (OR) are obtained from [60], also in [36], and [61]. Those scales were selected because they are aligned with the definition of opportunity recognition competency as the ability to find new ideas, i.e., a cognitive skill. We decided to delete one of the [60] items because it was built in negative form, and research shows that an unbalanced scale design (very few negatively worded items) can introduce ambiguity in results by non-attendance to the negative item content [62]. So, in this work, OR is operationally defined as self-perceived capabilities to recognize opportunities.

The questions are translated into Spanish using [63] method i.e., one author translates from the source (English) to the target (Spanish), and another author blindly translates back from the target to the source. Versions were examined by independent raters for meaning errors. Errors were corrected and the new versions were examined for new independent raters. Finally, we obtained a Spanish version. All items are shown in Table 1.

TABLE I

Alertness. [53] Scanning and search (AL)
AL_1 - I have frequent interactions with others to acquire new information.
AL_2 - I always keep an eye out for new business ideas when looking for information.
AL_3 - I read news, magazines, or trade publications regularly to acquire new information.
AL_4 - I browse the Internet every day.
AL_5 - I am an avid information seeker.
AL_6 - I am always actively looking for new information.
Entrepreneurship Education. [58; 36]
EE 1– My actual studies give me essential knowledge and tools to create my own company
EE 2 – Institutes would have to support company creation by students.
EE 3 – I would like to have more subjects in my institute about entrepreneurship.
EE 4 – The function to encourage entrepreneurship belongs to the institutes through education
Entrepreneurial Knowledge [59; 36]
EK 1 – I have the knowledge required to start a business.
EK 2 – The institute has helped me with getting the knowledge required to start a business
EK 3 – I have sufficient knowledge about specific training for young entrepreneurs
Opportunity Recognition (OR) [61] [50]
OR_1 - While going about routine day-to-day activities, I see potential new venture ideas all around me.
OR_2 - Recognizing a good opportunity usually requires experience in a specific industry or marketplace.
OR_3 - Discussions with my family or friends can help me to recognize business opportunities.
OR_4 - I am alert or sensitive toward new venture opportunities. (5)

D. Data analysis

First, we conducted an exploratory factor analysis to validate the AL, EE, EK, and OR measures. Maximum Likelihood analysis was utilized for factor extraction, and the

Varimax rotation method was used to transform the final factor solution into a simple solution. We obtained correlations between the mean level of constructs.

Second, we know that cross-sectional data cannot describe a causal-effect relationship. Despite the above, we explored the probabilistic existence of causal-effect relationships so, we made regressions between entrepreneurship experience and AL, EE, and EK constructs on OR. We made a T-student test for the dichotomic (Yes/No) entrepreneurship experience variable and OR, AL, and EK constructs.

Finally, to triangulate the results we use statements with significant correlations between them to make a semantic logical analysis to support our inferences

IV. Results

A. Quantitative analysis of response options

In the next lines, we describe the statistics. The complete statistical analyses can be found in the Appendix. Descriptive statistics are in Table II

Table II
Descriptives statistics

	N	Min.	Max.	Mean	Desv. típ.
gender	358	0	1	,77	,424
Educat. level	358	1	3	1,97	,589
tenure	358	0	29	6,10	5,887
Work exp.	358	0	35	14,74	8,071
Entrep. Exp.	358	0	1	,54	,499
EE_1	358	1	5	3,80	1,041
EE_2	358	1	5	4,11	1,014
EE_3	358	1	5	4,17	,948
EE_4	358	1	5	4,14	,986
EK_1	358	1	5	3,62	1,018
EK_2	358	1	5	3,38	1,026
EK_3	358	1	5	2,66	1,062
OR_1	358	1	5	3,85	,934
OR_2	358	1	5	3,72	,972
OR_3	358	1	5	4,03	,839
OR_4	358	1	5	3,60	,993
AL_1	358	1	5	3,77	,988
AL_2	358	1	5	3,78	,983
AL_3	358	1	5	3,58	1,055
AL_4	358	1	5	4,53	,773
AL_5	358	1	5	4,10	,879
AL_6	358	1	5	4,13	,847
Age	358	20,25	74,03	37,2430	8,09345
N valid	358				

Regarding AL, we obtained a unidimensional construct (Table III with a KMO of .747 and a Cronbach's alfa of .767. We validated the AL construct using [64] recommendations. So, the convergent validity is accepted when inter-item correlations are significant. Also, the discriminant validity is accepted when the inter-item partial correlations controlled by the mean value of the construct are not significant.

TABLE III
Factorial Matrix

	Factor
	1
AL_1	,749
AL_2	,756
AL_3	,593
AL_5	,577
AL_4	,454

Extraction Method: Maximum Likelihood.

a. 1 factor extracted. 4 iterations required

Regarding EE, we obtained unidimensional construct (Table IV) with a KMO of .702 and a Cronbach's alfa of .811. We validated the EE construct using [64] recommendations.

TABLE IV
Factorial Matrix

	Factor
	1
EE_2	,675
EE_3	,818
EE_4	,816

Extraction Method: Maximum Likelihood.

a. 1 factor extracted. 3 iterations required

Regarding EK, we obtained unidimensional construct (Table V) with a KMO of .700 and a Cronbach's alfa of .811. We validated the EK construct using [64] recommendations.

TABLE V
Factorial Matrix

	Factor
	1
EK_1	0,69
EK_2	0,765
EK_3	0,541

Extraction Method: Maximum Likelihood.

a. 1 factor extracted. 4 iterations required

Regarding OR, we obtained a unidimensional construct (Table VI) with a KMO of .679 and a Cronbach's alfa of .718. We validated the OR construct using [64] recommendations.

TABLE VI
Factorial Matrix

	Factor 1
OR_1	,700
OR_3	,642
OR_4	,695

Extraction Method: Maximum Likelihood.

a. 1 factor extracted. 3 iterations required

Correlations between the mean level of constructs and context variables are in Appendix.

Regarding hypotheses. Hypothesis 1a argues that higher levels of AL are related to higher levels of OR. Results show a significant (< .01) positive correlation between them. Hypothesis 1b refers to the relationship between EK, EE, and entrepreneurship experience with AL. Results show a significant positive correlation between them.

Hypothesis 2a refers to the relationship between EE and OR. Results show a small and significant (< .01) positive correlation. Hypothesis 2b refers to the relationship between EK and OR. Results show a significant (< .01) positive correlation. Hypothesis 2c refers to the relationship between entrepreneurship experience and OR. Results show a small and significant (< .01) positive correlation.

On the other hand, there is a significant (< .05) positive correlation between age and EE, and between educational level and OR. Other context variables do not have a significant relationship with OR, EE, AL, and EK. Finally, there are logical and positive correlations between age, educational level, tenure, and work experience.

We explored clues of causal-effect relationships by regressions. Regression shows that AL may have a significant positive effect on OR.

TABLE VII
Predictive Validity AL

Model		Coef. no standard		Coefficients typification	t	Sig.	Confidence Interval 95,0% for B	
		B	Error tip.	Beta			Limit inferior	Limit superior
1	(Constant)	1,063	,178		5,975	,000	,713	1,413
	mean_AL	,700	,044	,642	15,782	,000	,613	,788

a. Variable dependent: mean_OR

Regression shows that EE may have a significant positive effect on OR (Table VIII) and EK could have a significant positive effect on OR (Table IX).

TABLE VIII
Predictive Validity EE [a]

Model		Coef. no standard		Coefficients typification	t	Sig.	Confidence Interval 95,0% for B	
		B	Error tip.	Beta			Limit inferior	Limit superior
1	(Constant)	2,925	,191		15,285	,000	2,549	3,302
	mean_EE	,218	,045	,247	4,819	,000	,129	,308

a. Variable dependent: mean_OR

TABLE IX
Predictive Validity EK [a]

Model		Coef. no standard		Coefficients typification	t	Sig.	Confidence Interval 95,0% for B	
		B	Error tip.	Beta			Limit inferior	Limit superior
1	(Constant)	2,668	,146		18,316	,000	2,381	2,954
	mean_EK	,361	,044	,400	8,229	,000	,275	,447

a. Variable dependent: mean_OR

Regression shows that entrepreneurship experience could have a significant positive effect on OR (Table X). We did a T-student test for the dichotomic item entrepreneurship experience. The result is a significant positive mean value difference in OR and AL but not in EK.

TABLE X
Coefficient entrepreneurship experience [a]

Model		Coef. no standard		Coefficients typification	t	Sig.	Confidence Interval 95,0% for B	
		B	Error tip.	Beta			Limit inferior	Limit superior
1	(Constant)	3,671	,057		64,827	,000	3,559	3,782
	entrep_exp	,293	,077	,198	3,812	,000	,142	,444

a. Variable dependent: mean_OR

Finally, we make a regression by stages between entrepreneurship experience, EE, EK, and AL on OR (tables XI and XII) the results could suggest total mediation from AL on the relationships between EE with OR and the relationship between entrepreneurship experience and OR.

TABLE XI
Total mediation for EE[a]

Model		Coef. no standard		Coefficients typification	t	Sig.	Confidence Interval 95,0% for B	
		B	Error tip.	Beta			Limit inferior	Limit superior
1	(Constant)	2,925	,191		15,285	,000	2,549	3,302

	mean_EE	,218	,045	,247	4,819	,000	,129	,308
2	(Constante)	,886	,205		4,318	,000	,482	1,289
	mean_EE	,064	,037	,073	1,716	,087	-,009	,137
	mean_AL	,678	,046	,621	14,701	,000	,587	,769

a. Variable dependent: mean_OR

TABLE XII

Total mediation for entrepreneurship experience [a]

Model		Coef. no standard		Coefficients typification	t	Sig.	Confidence Interval 95,0% for B	
		B	Error tip.	Beta			Limit inferior	Limit superior
1	(Constante)	3,671	,057		64,827	,000	3,559	3,782
	entrep_exp	,293	,077	,198	3,812	,000	,142	,444
2	(Constante)	1,067	,177		6,014	,000	,718	1,415
	entrep_exp	,110	,061	,074	1,789	,074	-,011	,230
	mean_AL	,684	,045	,627	15,164	,000	,596	,773

a. Variable dependent: mean_OR

In summary, we found four unidimensional constructs: AL, EE, EK, and OR. There is a positive correlation between AL, EE, and EK. Also, AL, EE, EK, and the antecedent of respondents' entrepreneurship experience show a significant positive correlation with OR. The context variables of age, and educational level, show a positive correlation with EE and OR respectively. Regressions show clues of a positive influence from AL, EE, EK, and entrepreneurship experience on OR. Finally, results show clues of a total mediation of AL on the relationship between EE and OR, and the antecedent of entrepreneurship experience and OR.

B. Semantic analysis of the item statements

We analyzed selected item statements and their semantic relationship. First, we describe the composition of OR, EE, EK, and AL constructs. Second, we selected statements with significant correlations ($p < .01$) between them (see Appendix). Each author reads iteratively the statements looking for semantic logical links between them. After that we discuss each semantic logical link until reach a consensus, the final results are described next.

In this work OR construct encompasses: OR_1 (*While going about routine day-to-day activities, I see potential new venture ideas all around me*); OR_3 (*Discussions with my family or friends can help me to recognize business opportunities*); and OR_4 (*I am alert or sensitive toward new venture opportunities*).

EE encompasses EE_2 (*Institutes would have to support company creation by students*), EE_3 (*I would like to have more subjects in my institute about entrepreneurship*), and EE_4 (*The function to encourage entrepreneurship belongs to the institutes through education statements*).

EK encompasses EK_1 (*I have the knowledge required to start a business*), EK_2 (*The institute has helped me with getting the knowledge required to start a business*), and EK_3 (*I have sufficient knowledge about specific training for young entrepreneurs*).

AL encompasses AL_1 (*I have frequent interactions with others to acquire new information*), AL_2 (*I always keep an eye out for new business ideas when looking for information*), AL_3 (*I read news, magazines, or trade publications regularly to acquire new information*), AL_4 (*I browse the Internet every day*), and AL_5 (*I am an avid information seeker*).

First, we can say that both EE_2 and EE_4 have a significant positive correlation with EK_2, also there is a semantic link between them because their statements are referred to the institutions' positive role in entrepreneurship. That semantic link may explain the positive relation between EE and EK ($p < .05$).

Second, all EK item statements referred to have some type of entrepreneurial knowledge which could enhance communication with families and friends (OR_3), imagination (OR_1), and focusing on business venturing (OR_4) explaining semantically the clue of a positive effect of EK on OR.

Third, the clue of the positive effect of EE on OR could be semantically explained considering that all the statements of EE are referred to have expectations about education institutions. Respondents are all on the run, so logically, expectations have not been disconfirmed already. Respondents' expectation allows them to communicate (OR_3), imagine (OR_1), and focus on new opportunities (OR_4).

Regarding AL, there is a semantical link between AL_1 (frequent interactions) and AL_5 (information seekers) with AL_3 (read news to acquire new information). Through discussions with family and friends (OR_3), we could obtain information about business opportunities. On the other hand, acquiring new information regularly (AL_3), browsing the internet daily, and looking for information about new business ideas (AL_2) are semantically related to focusing on new venture opportunities (OR_4). So, all that logical linking may reinforce the clue of the positive effect of AL on OR.

Regarding the total mediation of AL on the relationship between entrepreneurship experience and OR, it has already been suggested [65]. The mechanism associated could be the change in entrepreneurs' mental model because we know that attention can trigger changes in individuals' mental model by assimilation or accommodation [26; 27]. So, it is logical to think that new information may distort or enhance the entrepreneurs' mental model capability to recognize (or not) new business opportunities.

Regarding the clue of total mediation of AL on the relationship between EE and OR we already said that the effect of EE on OR could be logically explained for expectations about education institutions. Those expectations can be reduced or enlarged by new information (AL_1, AL_2, AL_5) obtained through magazines, trade publications (AL_3), or the internet (AL_4).

V. Discussion

Engineers need opportunity recognition capabilities to achieve innovative and creative responses in the market. Firms and educational institutions require an understanding of the cognitive dynamic associated with developing such

capabilities. We explore some of those dynamics, specifically the relationship between entrepreneurial mental models, alertness, and opportunity recognition.

We measured alertness (AL) and opportunity recognition (OR) with scales generally used. Given the difficult-to-obtain mental models, we use three proxies: the antecedent of entrepreneurship experience and scales of entrepreneurial knowledge (EK) and entrepreneurial education (EE). We sample students from the engineering domain with work experience because we can suppose that they have mental models associated with the market.

Regarding the results. First, we must highlight that as predicted by [21] AL could influence positively the OR. It also confirms that the entrepreneurs' alertness makes them more prone to recognize and discover opportunities [19]. Based on item statements we can say that the information seekers (Al_5) could make frequent interactions with others (AL_1) such as family and friends to acquire new business information (OR_3). At the same time reading magazines or trade publications (AL_3) and browsing the Internet (AL_4) could be associated with focusing on new ventures (OR_4).

Second, the EE, EK, and entrepreneurial experience could have a significant positive impact on AL confirming that the mental model directs people's attention to causal relationships to forecast alternative solutions. Entrepreneurial mental models may have a positive effect on respondents' behaviors of scanning and searching such as frequent interactions with others (AL_1), reading trade publications (AL_3), and browsing the Internet (AL_4).

Third, EK could influence positively the OR which could confirm previous results [36]. The item statements referred to knowing how to start a business (EK_1 and EK_2) and knowing specific training for younger entrepreneurs (EK_3) implied the existence of knowledge structures. All those mental models are used to reason, filter, and store new information [47; 48; 45; 49] producing individual behaviors such as discussing with family or friends (OR_3), imagining new ventures ideas (OR_1) or focusing on new venture opportunities (OR_4).

Fourth, EE could positively influence the OR through the procedures for shaping enterprising skills [36]. Semantically, the EE item statements refer to expectations about institutions' role in supporting company creation (EE_2), in teaching subjects about entrepreneurship (EE_3), and in encouraging entrepreneurship (EE_4). Interestingly we are talking about expectations that produce the behaviors of discussion with family or friends (OR_3), imagining new venture ideas (OR_1), or focusing on new venture opportunities (OR_4).

Fifth, the antecedent of entrepreneurship experience could positively influence the OR through prior experiences that shape new perceptions and affect the match between market events and entrepreneurs' mental models [37; 32; 29; 21]. The antecedent of entrepreneurship experience is correlated positively and significantly ($p < .01$) with imagining new venture ideas (OR_1) and focusing on new venture opportunities (OR_4).

Sixth, the AL construct could mediate totally the relationship between both the antecedent of entrepreneurship experience and the EE construct with OR [65]. Total mediation could be explained through changes in individuals' mental models and changes in educational expectations triggered by behaviors of attention [26; 27] such as frequent interactions with others (AL_1), reading trade publications (AL_3), and browsing the Internet (AL_4).

Seventh, considering the above we may question: Why does AL not mediate the relationship between EK and OR? The statements in EK referred to having a certain knowledge about starting a business, as we know entrepreneurs could use biases and heuristics such as representativeness (generalizing from limited experience) and overconfidence (overly optimistic assessment of situations) [66]. Therefore, if they recognize a business opportunity, they can think that searching for new information is not required.

In summary, according to the above, we can infer that the entrepreneurial mental model, alertness, and opportunity recognition have a nonlinear dynamic relationship. In engineers' minds, there is a self-organization dynamic between cognitive structures that support the cognitive processes that form and change them. That dynamic defines engineers' behaviors such as opportunity recognition. So, enhancing the engineers' opportunity recognition skills requires increasing entrepreneurial mental models and alertness at the same time triggering the nonlinear dynamic between them like a virtuous circle if you will. That definition is quite different from cognitive OR lineal models [14; 67; 68] In this context, teaching how to make a business plan is not enough.

VI. Conclusion

We sampled working professionals and technicians currently studying engineering as another profession and engineering post-degree students. Through a self-applied survey, we measured the entrepreneurship experience antecedent and the level of EE, EK, AL, and OR, inferring a potential cause-effect relationship. Also, we evaluated the effects of age, tenure, work experiences, educational level, and functional specialization.

The quantitative analysis of the response options confirms that EE, EK, AL, and OR are unidimensional constructs. There is a positive correlation between AL, EE, and EK. Also, AL, EE, EK, and the antecedent of respondents' entrepreneurship experience show a significant positive correlation with OR. The context variables of age, and educational level, show a positive correlation with EE and OR respectively. Regressions show clues of a positive influence from AL, EE, EK, and entrepreneurship experience on OR. Finally, results suggest a total mediation of AL on the relationship between EE and OR, and the antecedent of entrepreneurship experience and OR. Later we triangulated the results by a semantic analysis of the selected item statements. In summary, we found a no-linear relationship between cognitive structures and processes, which in our knowledge has not been described until now.

This study makes two theoretical contributions. First, we explore the relationship between engineers' cognitive processes (i.e., alertness) and cognitive structures (i.e., mental models) and their effect on entrepreneurial skills (i.e., opportunity recognition capability). Second, we make an epistemological contribution to entrepreneurial cognitive

literature using a semantic perspective to triangulate the research results through item statements.

This study makes some practical contributions to engineering education. First, it shows that developing an entrepreneurial mindset may require acting on the relationship between cognitive structures and processes to trigger a nonlinear dynamic using non-traditional training methods. Second, it shows that an entrepreneurial mindset requires both entrepreneurship experience and entrepreneurial knowledge at the same time, so firms and education institutions must provide them.

This work has limitations. First, items used allow only an initial exploration, future research requires new items specifically associated with entrepreneurial professionals. Second, we removed two of three dimensions of AL scale which can affect the conceptual validity of the results obtained. Future research should apply the complete scale comparing both results. Third, the use of survey implies potential self-report biases. Future research must use objective measures of entrepreneurial behaviors. Fourth, the sample encompasses a mix of engineering students and professionals so the generalization to current engineers in management or entrepreneurial roles is limited. Future research must select only entrepreneurial engineers. Fifth, despite the semantic analysis of item statements we recognize that the risk of common method bias remains. Future research must consider additional qualitative methods of triangulation. Finally, the sample only belongs to the Chilean country, future research requires a cross-cultural perspective.

Compliance with Ethical Standards

The authors declare that no funding was received.
Authors declare that they have no conflict of interest.
The participants received and accepted informed consent.

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