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Perception of low social pressure and lack of capacity reduces vaccination compliance – The case of lumpy skin disease

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Abstract

Successful prevention of epidemics depends on implementation of control measures, including vaccine compliance and maintenance of high vaccination coverage for long periods. However, to the best of our knowledge, a study of the temporal dynamics of compliance in voluntary vaccination campaigns and of the factors which influence them was never published. In this study, we investigated the factors influencing the dynamics of vaccination compliance against lumpy skin disease (LSD) after the occurrence of LSD epidemics in Israel in 2012–2013 and 2019. From 2016 to 2019, we followed voluntary LSD annual vaccination among a cohort of 566 farmers and used questionnaires based on the theory of planned behaviour to investigate the incentives influencing vaccine compliance among 90 farmers. The results showed a reduction in vaccination against LSD from 61% in 2016 to 27% in 2019 and a very strong association between prior vaccination and vaccination compliance. The actual vaccination by farmers who stated a positive intention to vaccinate was 4.5 times higher than farmers who did not (p-value = .007). However, half of the highly intended farmers eventually did not vaccinate their herd. These farmers were significantly more concerned by manpower and vaccine price compared to their vaccinating counterparts, pointing to vaccination effort perceptions as a major factor influencing compliance. In addition, we found that farmers who answered the questionnaires before the LSD epidemic of 2019 perceived significantly less pressure to vaccinate imposed by veterinary organizations (private and governmental) than farmers answering them during or after the epidemic. We conclude that the veterinarian-associated social pressure is a major compliance-enhancing factor, influenced by the occurrence of an epidemic. Our findings suggest that the deterioration of vaccination compliance after an epidemic can be mitigated by maintenance of pressure to vaccinate by veterinarians. Manpower support and vaccine discounts may be advocated to promote vaccine compliance.

KEYWORDS
epidemic, lumpy skin disease, theory of planned behaviour, vaccination compliance, vaccination compliance dynamics, voluntary vaccination

1 | INTRODUCTION

Vaccination is considered one of the most important measures of preventing and controlling both human and animal diseases. The success of every vaccination campaign is based on the vaccine characteristics such as its efficacy and safety and on vaccination coverage and compliance, which depend on human behaviour. The social–psychological factors influencing vaccination compliance have been widely studied, both in human medicine (e.g. Brewer et al., 2017; Chapman & Coups, 1999; Ratnapradipa et al., 2017; Schmid et al., 2017; Wheelock et al., 2013) and animal medicine (e.g. Elbres et al., 2010; Eschle et al., 2020; Gehrig et al., 2019). However, to our knowledge, investigation of the change of vaccination compliance through time (compliance dynamics) and the factors influencing it was never published. Such information is of primary importance, first for policymakers who wish to decide if vaccination against a certain disease should be mandatory or voluntary. Second, these data are essential for planning better intervention programmes to prevent deterioration of vaccination compliance.

To provide this information, we investigated the dynamics of Israeli dairy farmers' vaccination compliance against lumpy skin disease (LSD), a vector-borne viral disease. We chose LSD as it is considered one of the most significant diseases affecting cattle. LSD is caused by the lumpy skin disease virus (LSDV), a member of the Poxviridae family and the genus Capripoxvirus (Tuppurainen & Oura, 2012). The disease is mostly characterized by the occurrence of localized or generalized skin nodules. It is often accompanied by lethargy, reduced appetite, oedema, reduction in milk production and might even cause death (Tuppurainen & Oura, 2012). Until 2012, LSD was mainly limited to Africa with some sporadic incursions which caused epidemics in the Middle East. From 2012, the disease had spread to Israel, Turkey, Greece, Bulgaria and other Balkan countries, Armenia, Azerbaijan, Kazakhstan, Georgia, the Russian Federation, China, India, Bangladesh, Syria, Cambodia, Hong-Kong, Malaysia, Vietnam and Thailand (EFSA, 2017; EFSA et al., 2019; https://wahis.woah.org/#/events).

To date, most of the commercially available vaccines against LSD are live attenuated, based on a LSDV strain, sheeppox virus (SPPV) or goatpox virus (GTPV) (Tuppurainen et al., 2021). A commonly used vaccine is based on the attenuated Neethling LSDV strain. There is a strong evidence that the Neethling vaccine was effective at preventing disease in Israel in 2012 and in the Balkans during 2015–2017 (Ben-Gera et al., 2015; Klement et al., 2020). But the vaccination strategy, determined by the policymakers, varied in Israel. Five LSD epidemics occurred in Israel. The largest occurred in 2012 and lasted until August 2013. Thereafter, compulsory vaccination was implemented by the Israeli Veterinary Services (IVS). In June 2016, the IVS changed its policy and vaccination against LSD became voluntary. In 2019, a new epidemic of LSD occurred in Israel. These events allowed us to explore the dynamics of voluntary vaccination compliance among Israeli farmers and their relation to the occurrence of LSD.

For this purpose, we followed the annual vaccination compliance between 2016 and 2019 among a cohort of 566 Israeli dairy farmers insured by 'Hachaklait' (a veterinary cooperation, owned by the farmers, which provides veterinary services to about 80% of the dairy farms in Israel). In addition, we investigated the demographic and social–psychological factors influencing vaccination compliance among 90 dairy farmers using predefined questionnaires based on the theory of planned behaviour (TPB), a reasoned action approach. Such theories of reasoned action and planned behaviour are widely used in the study of medical behaviours (Albarracin et al., 2001; McEachan et al., 2016; Sok et al., 2021), including the motivation to vaccinate (Jozkowski & Geshnizjani, 2016; Sok et al., 2015).

The TPB predicts that a given future behaviour is explained by the intention to perform it. The intention is directly explained by three main constructs: attitude (A) (the person's favourable or unfavourable evaluation of the behaviour), subjective norms (SN) (the social pressures a person perceives to perform or not the behaviour) and perceived behavioural control (PBC) (the perceived own capability to perform that behaviour) (Ajzen, 1985). Further on, Fishbein and Ajzen developed the conceptualization of the TPB's predictors of intention and defined two distinguishable subdimensions to the existing unitary definition of attitude and perceived behavioural control. Attitude was divided to instrumental and experiential. The instrumental factor is the perceived ability of the behaviour to produce desirable or undesirable outcomes. The experiential factor is the perceived ability of the behaviour to be pleasant or unpleasant. The perceived behavioural control was divided to capacity and autonomy. Capacity reflects the perceived capability of performing a given behaviour, and autonomy reflects the degree to which people believe that the performance of the behaviour is up to them. Regarding the subjective norms, a distinction between injunctive and descriptive aspects was made. Injunctive norms refer to people's perceptions of what others would like them to do or what is expected of them. Descriptive norms refer to people's perceptions of what important others do.

The results of this study point to the major factors that influence both vaccination compliance and compliance deterioration. This reflects on the potential effectiveness of strategies to increase vaccination compliance.

2 | MATERIALS AND METHODS

2.1 | Study population and data collection

The study included two main datasets: (1) Vaccination and demographic data on 566 dairy farms insured by the 'Hachaklait' organization during the years 2016–2019 (Figure 1, Dataset 1). These data were collected from the 'Hachaklait' and included the type of herd (owned by family/cooperative/school), the district (which was classified into three geographic areas: north, centre and south) and payment for vaccination during the years 2016–2019. In addition, we collected information regarding the occurrence of an LSD epidemic in the herd during 2012–2013. (2) Ninety TPB questionnaires were filled out by dairy farmers regarding their intention to vaccinate against LSD (Figure 1, Dataset 2). These questionnaires were a subset of a larger survey performed among dairy farmers, inquiring about the intention to vaccinate against five cattle diseases. The questionnaires

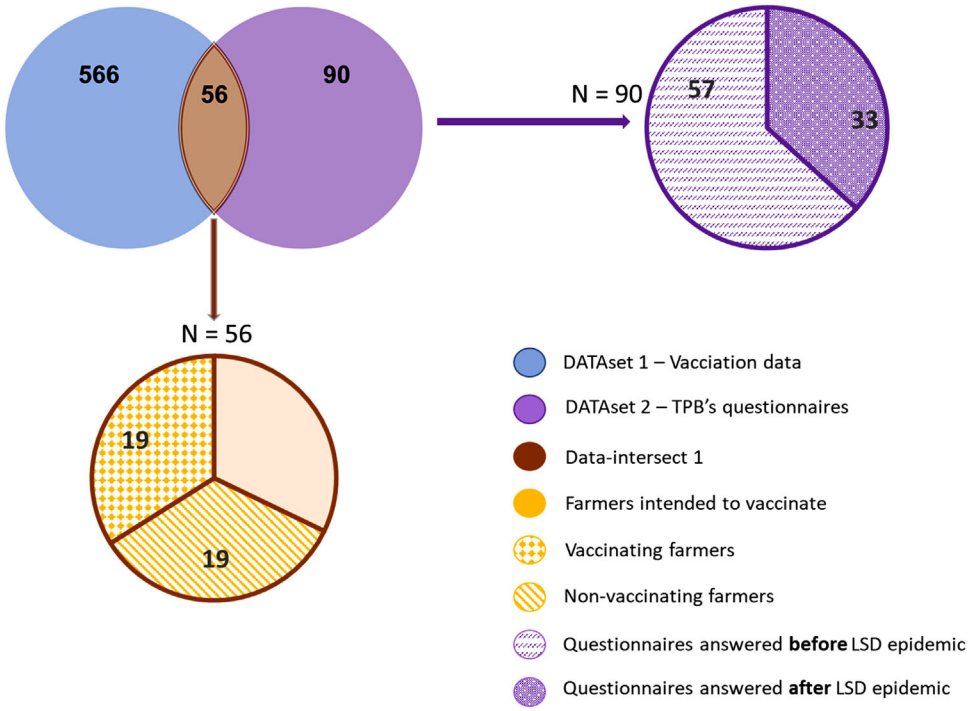

FIGURE 1 A graphic description of the study population. The study included two main datasets: (1) Vaccination and demographic data on 566 dairy farms insured by the Hachaklait organization during the years 2016–2019 (Dataset 1). (2) Ninety TPB questionnaires filled-in by dairy farmers regarding their intention to vaccinate against LSD (dataset 2). The intersection between these datasets yielded 56 questionnaires, for which we had data on voluntary vaccination (Data-intersect 1). These 56 questionnaire included 38 questionnaires filled-in by farmers who intended to vaccinate against LSD in the coming year. Half of these 38 farmers vaccinate their herds in 2019, while the other half did not. Dataset 2 was divided to 57 questionnaires which were filled-in before the 2019 epidemic and 33 after

were distributed at the annual Israeli cattle conference, which was held in December 2018, and in 13 following conferences, seminars, professional training courses and other meetings organized by the dairy farmers during the years 2019–2020. We intersected these two datasets to study the association of intention with actual vaccination. The intersection yielded 56 questionnaires. We could not intersect the remaining 34 questionnaires due to the lack of identifying details (Figure 1, Data-intersect 1).

2.2 | The TPB questionnaire

The TPB is a theoretical framework but also comprises a set of guidelines to ensure proper measurement of the social–psychological constructs. A crucial step in applying the TPB is to define the behaviour in terms of its target, the action itself, the context in which it is performed and when it is performed (the TACT principle). Then, to conduct a pilot study in which readily accessible behavioural outcomes, normative referents and control factors regarding the behaviour are elicited (Francis et al., 2004; Sok et al., 2021). Our pilot study included semiqualitative interviews with 20 dairy farmers during October–November 2018 (of them, seven dairy farmers were asked about vaccination against LSD). This gave us a set of underlying beliefs for each of the constructs (A, SN and PBC). The interviews, as well as the questionnaire construction, were based on previous studies (Francis et al., 2004; Sok et al., 2015, 2016).

The questionnaire included three parts:

1. Questions measuring background factors. These factors were classified into farm and behavioural variables. The farm variables included questions on the type of the herd (family farm vs. single/double/triple cooperative farms), the herd's yearly milk quota and the location of the herd. The behavioural variables included questions measuring perceived past experience and perceived risk as well as general questions regarding the gender, education and age of the farmer. Perceived risk was measured by the relative risk attitude and the risk perception. Risk perception was measured by multiplying two 7-point Likert-type scales, one with frequencies from 'once in 100 years' to 'once in a week' and one with the adjectives 'No impact' up to 'High impact'. For measuring the relative risk attitude (with respect to animal diseases in general), each farmer was asked to compare his/her general risk perception to other farmers. This was performed by filling a 5-point Likert type scale that ranged from 'absolutely disagree' to 'absolutely agree', regarding four statements (Meuwissen et al., 2001). The TPB framework suggests that the background factors could explain variation in the intention. However, we examined whether these factors also have a direct effect on the intention.

2. Questions to obtain direct measures of the constructs of the TPB. A 5-point semantic differential scale with four different bipolar adjective pairs (e.g. unsatisfying and satisfying) was used to obtain direct measures of attitude. Injunctive subjective norm and PBC were measured with 5-point bipolar Likert-type scales with the endpoints 'disagree' to 'agree' (Sok et al., 2016). To prevent misinterpretation of questions regarding negative beliefs, two adjective pairs and one PBC statement were recoded so that higher numbers always reflect a positive attitude/self-efficacy/controllability to the target behaviour. Behavioural intention was measured by asking the farmer to scale his/her intention to vaccinate against LSD in the coming year between 1 (will certainly not vaccinate) to 5 (will certainly vaccinate). The survey only queried for measures of the injunctive norm.

   Given the distinction between reflective and formative measurement, direct measures are required to show high internal consistency (see also Sok et al., 2021). We tested the internal consistency of the direct indicator for each construct by using the Cronbach's alpha scores. This analysis revealed a low internal consistency in the direct measures of the SN and PBC constructs (α = .6, .2, respectively) (Table S1). The indicator Nd3, which was based on the question 'I feel I have social pressure to vaccinate my herd against LSD in the coming year', had low within-construct correlations with the other two indicators (< 0.3) and was not correlated with the intention indicators (Table S1). This can be explained by the disagreement of the farmers with the firmer wording of this statement as compared to the other two statements. Regarding the PBC, all three indicators were not correlated with each other. However, as opposed to indicators Pd1 and Pd2, the indicator Pd3, which was representing the capacity dimension, did correlate with the intention (Table S1). In addition, although the internal consistency was appropriate for attitude (∝C value of 0.8), only the indicators Ad1 and Ad2, which reflected experiential considerations ('necessary', 'contribute'), had high within-construct correlations and were correlated with intention (Table S1). Overall, to solve for the low internal inconsistency, we assessed only the indicators which were correlated with the intention (Ad1 and Ad2 for attitude, Nd1 and Nd2 for norms, Pd3 for PBC). We calculated the mean of these indicator scores to give an overall score for each construct.
3. Questions to obtain indirect (belief-based) measures of the three social–psychological constructs (A, SN and PBC). The most frequently mentioned responses from the qualitative part of the study were used to formulate behavioural, normative and control belief items. Consistent with the expectancy-value model, for each item, the belief strength is measured at a scale of 5-point Likert type that ranged from 'not very likely' to 'very likely' for attitude's beliefs, from 'very against' to 'very in favour' for subjective norms' beliefs and from 'not true' to 'very true' for PBC's beliefs. Since the subjective norms' statements had negative/positive meanings, we used a bipolar scaling, while we used a unipolar scaler for the attitude's and PBC's statements. The outcome evaluation/motivation to comply with pressure from the reference group/power of the control were measured at a scale of 5-point Likert type that ranged from 'very unimportant' to 'very important'/'not important' to 'very important'/'more difficult' to 'more easy'. This time, the power of the control received a bipolar scaling and the motivation to comply a unipolar scaling. In the analysis, we changed the outcome evaluation scaling from bipolar to unipolar which was more logically fit (see Sok et al., 2021). Certain behavioural and control belief statements with expected negative influence on vaccination were recoded has been described for the direct measurement. The resulting multiplicative products were analysed both individually and as an average.

The full questionnaire is attached to the supplementary materials.

2.3 | Data analysis

2.3.1 | Prediction of vaccination compliance against LSD in 2019 by previous vaccination

We examined the influence of the following factors on LSD vaccination in 2019 among 566 farmers: previous vaccination (divided into four categories: 1 No previous vaccination. 2. Vaccination only in 2017. 3. Vaccination only in 2018. 4. Vaccination in both 2017 and 2018), farm type (family vs. cooperative vs. school), geographic area (North, Centre and South of Israel) and previous occurrence of the disease in the herd (yes/no). Univariable analysis was performed by using the Chi-square test. Multivariable analysis was performed by fitting a logistic regression model to the 2019 vaccination data. Variables were included in the model in a forward stepwise process with a p-value of .05 in the univariable analysis as a cut-off for inclusion and a p-value > .05 in the multivariable analysis as a cut-off value for variable exclusion.

2.3.2 | Analysis of attitude, subjective norms and perceived behavioural control among farmers

We used the intersection data (Figure 1) for determining the association of the three constructs with actual vaccination among farmers who showed high intention to vaccinate. Thirty-eight of the 56 dairy farmers intended to vaccinate their herd (scores 4–5) (Figure 1). Vaccination records for the period preceding questionnaire filling were available for half of these 38 (future behaviour). For the other half, we had data on recent vaccination behaviour (up to 1 year prior to questionnaire filling). Within this group, we compared the three constructs' direct and indirect measurements between those who did and did not vaccinate.

For determining the association of the three constructs with intention among the 90 farmers (Figure 1, Dataset 2), we compared A, N and PBC between farmers with negative and positive intention to vaccinate. We performed univariable analysis for each construct's direct and indirect measurement using T tests. The intention was analysed as a dichotomic variable, scores 1–2–3 were marked as a negative intention and scores 4–5 as a positive intention. The same was performed for each belief. Similarly, we determined the direct effect of the

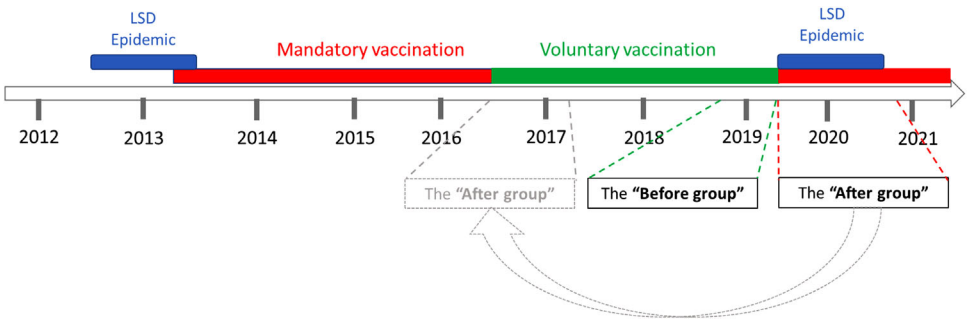

FIGURE 2 Outline of vaccination strategy and LSD epidemic in Israel between 2012 and 2021. Green – periods of voluntary vaccination. Red – mandatory vaccination. The questionnaire study groups and the study rational are depicted by the rectangles in the bottom of the figure. The 'after group' represents questionnaires filled during and after the epidemic onset in 2019. The rational is that the 'after group' counterfactually represents the situation immediately after ceasing mandatory vaccination in June 2016.

background variables (farm and behavioural) on the intention to vaccinate. In that univariable analysis, we used Fisher/Chi-square tests.

2.3.3 | Effect of distance in time from LSD epidemic on the intention to vaccinate and the three constructs' direct and indirect measurements

Ideally, we would have distributed the questionnaires each year and followed the change in these factors. However, the questionnaire study began only in 2018, and data on vaccination intention in preceding years were not available. In 2019, during the questionnaire study, another LSD epidemic took place in Israel. This epidemic enabled us to compare questionnaires filled in by farmers before the epidemic and after the epidemic. Fifty-seven questionnaires were answered before this epidemic while 33 questionnaires were answered during and after its occurrence (Figure 1). These 33 questionnaires represent a status resembling the situation after the epidemic of 2012–2013, when vaccination became voluntary. The questionnaires which were answered before the epidemic in 2019 (the 'before' group) represent the situation long after the epidemic in 2013 (Figure 2). The comparison between the before and during/after the epidemic in 2019, therefore, represent different time distances from an LSD epidemic. Comparing the intention to vaccinate and the three constructs' direct and indirect measurements between the two groups was performed by using t tests after ensuring that the data were normally distributed.

Intention to vaccinate was modelled using the data of 90 RAA questionnaires. A general linear model of intention to vaccinate was fitted to the farmers' beliefs, the location of the herd and the time from the last epidemic ('before' or 'after') as the explanatory variables. The model was fitted using a stepwise process with a *p*-value of .05 in the multivariable analysis as a cut-off value for variable exclusion.

All statistical analysis was performed using R version 3.6.0 (R Core Team, 2019), the '*dplyr*', '*ltm*', '*Hmisc*', '*olsrr*' and '*lme4*' packages (Bates et al., 2015; Harrell et al., 2021; Hebbali, 2020; Rizopoulos, 2006; Wickham et al., 2020).

3 | RESULTS

3.1 | Vaccination compliance

Between 2016 and 2019, we followed the annual vaccination compliance among 566 cattle herd owners insured by 'Hachaklait' (the veterinary cooperation providing private veterinary services to the farmers). As depicted in Figure 3, we observed a reduction in vaccination against LSD from 61% in 2016 to 27% in 2019. We also found that farmers who withdrew from vaccination were less likely to vaccinate in the following years. Farmers who vaccinated their herds only in 2017 were more than eight times more likely to vaccinate their herds in 2019 as compared to the farmers who did not vaccinate their herds in 2017 and 2018. The difference between farmers who did not vaccinate in both years to farmers who vaccinated in both years was even more striking, where the latter was 120 times more likely to vaccinate in 2019 (Table 1). A strong association was also found between vaccination and the geographical location of the herd; farmers whose herd was located in the centre of Israel were 20 times less likely, to vaccinate than farmers whose herd was located in the north (Table 1).

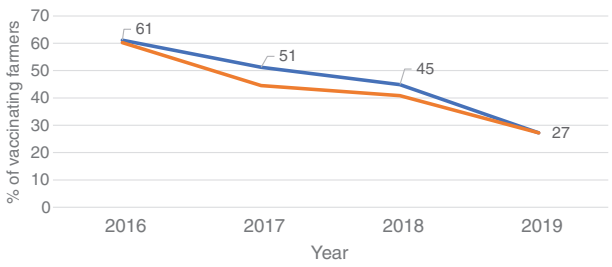

FIGURE 3 The annual percentage of vaccination for lumpy skin disease (LSD) among 566 Israeli dairy farmers during years 2016–2019. The blue line represents the percentage of policyholders who vaccinated during January-December, except for 2019 (during which vaccination became mandatory in June). The orange line represents percentage of policy-holders who vaccinated only during January–May in each year.

TABLE 1 The association between previous vaccination and geographic area to lumpy skin disease (LSD) vaccination in 2019

Covariate		OR (95% CI) for vaccination in 2019	*p*
Previous vaccination	None	Ref	NA
	Only in 2017	8.39 (2.53; 32.46)	<0.001
	Only in 2018	11.89 (1.15; 69.41)	0.007
	In 2017 and 2018	119.54 (47.47; 403.43)	<0.001
Geographic area	North	Ref	NA
	Center	0.05 (0.01; 0.18)	<0.001
	South	0.63 (0.35; 1.08)	0.1

Note: A multivariable logistic regression on 566 'Hachaklait' policyholders.

3.2 | Analysis of intention to vaccinate

To find the causes for this reduction in vaccination compliance, we distributed 90 questionnaires (Figure 1), based on the TPB model, among Israeli dairy farmers (see detailed description in the methods section). These questionnaires were analysed in a two-stage approach. We first wished to characterize the factors determining the farmers' intention to vaccinate as a proxy for vaccination behaviour. At the next stage, we aimed to explore which of these factors was both likely to change with time and influence vaccination compliance.

Before the characterization of the factors influencing intention, we wished to test the assumption that in our data the intention to vaccinate represents vaccination behaviour. For this purpose, we used the 56 questionnaires for which we had data on voluntary vaccination (Figure 1, Data-intersect 1). Vaccination among farmers who claimed they are likely to vaccinate was 4.5 times higher (p-value = .007) compared to vaccination among nonintenders (2/18). Analysis of 33 of these farmers for which we had data on future behaviour showed a similar result though only marginally significant ($p = .067$). Surprisingly, despite this strong association, only 19 out of the 38 (50%) farmers who claimed they are likely to vaccinate indeed vaccinated their herd (Figure 1). The vaccinating farmers showed a stronger belief in the ability of the vaccine to reduce clinical signs of LSD (Table 2). However, the most prominent difference between vaccinating and nonvaccinating farmers was recorded in the indirect measurement of the PBC. Specifically, these farmers were less concerned about the vaccine's cost and the time and manpower required for vaccination (Table 2).

We next analysed the entire set of 90 questionnaires to identify the factors that determine vaccination intention. Among the background factors, farmers whose herds were located in the centre of Israel and felt lower perceived risk regarding the frequency and consequences of an LSD epidemic showed less intention to vaccinate their herds (Table S2a,b). Furthermore, as expected, higher vaccination intention was associated with both direct and indirect measurements of the three RAA constructs: attitude, subjective norms and perceived behavioural control (Table S3). Among the attitude factors, the highest influence was recorded for the perceptions regarding the benefit from vaccination, reduction of the severity of clinical signs, receiving money from the insurance company, peace of mind and reducing the number of disease cases. Farmers' intention to vaccinate was significantly influenced by all the nine investigated subjective norm factors. Finally, among the PBC factors, the most influential were the vaccine's cost and information on the vaccine's effectiveness (Table S3).

At the following stage, we attempted to determine which of these factors have changed as time elapsed from the LSD epidemic in 2012 and might have caused the reduction in vaccination during 2016–2019. As explained in the 'Materials and Methods', since we could not measure the actual change of beliefs during this period we used the comparison between farmers' answers before and after the 2019 epidemic as a proxy for the farmer's change of beliefs shortly after the epidemic and long after an epidemic. When comparing these two groups, we found that after the 2019 epidemic, the farmers showed higher intention to vaccinate (Table 3). Furthermore, vaccination norms among farmers who answered the questionnaires before the epidemic in 2019 were significantly lower than the norms among farmers answering the questionnaires after the epidemic (Table 3). Specifically, after the epidemic, the farmers perceived a stronger recommendation for vaccination by the 'Hachaklait' and the veterinary services (Table 3). In addition, after the epidemic, the farmers were more concerned about the vaccine's adverse reactions, although the overall attitude was not significantly different between the two groups (Table 3). These findings suggest a possible connection between a post epidemic change in these specific norms and a change in vaccination intention.

The multivariable linear regression revealed four statistically significant factors associated with farmers intention to vaccinate: the time of questionnaire filling (higher for after the 2019 epidemic), the farm location (lower in the centre of Israel), the farmer's perceived recommendation to vaccinate by the private vet and the farmer belief that the vaccine will be economically beneficial (Table 4).

4 | DISCUSSION

To the best of our knowledge, this is the first study, both in human and veterinary medicine, that investigates the dynamics of vaccination compliance and the factors which influence its deterioration after an epidemic. The results of this study show that vaccination compliance diminishes as time elapses from an epidemic. The main factor

TABLE 2 Comparison of the average direct and indirect measurements of attitude, norms and PBC, between LSD vaccinating and nonvaccinating farmers (in 2019) who showed high intention to vaccinate

		Past and future behaviour			Future behaviour		
		No ($N = 19$)	Yes ($N = 19$)		No ($N = 10$)	Yes ($N = 9$)	
Vaccinating in 2019		Mean (SD)	Mean (SD)	T.test, *p* value	Mean (SD)	Mean (SD)	T.test, *p* value
Direct	Attitude	3.11 (1.55)	3.58 (1.50)	.345	3.85 (1.33)	3.78 (1.56)	.915
	Norms	3.97 (1.05)	4.42 (0.85)	.158	3.95 (0.90)	4.78 (0.51)	.026
	PBC	4.74 (0.56)	4.79 (0.42)	.745	4.70 (0.67)	4.78 (0.44)	.773
Indirect	Attitude	17.82 (3.86)	19.20 (3.38)	.247	16.93 (3.87)	20.26 (2.48)	.042
	A2 (Reducing the severity of clinical signs)	17.68 (5.93)	22.10 (3.03)	.006	16.10 (6.21)	22.22 (2.63)	.014
	Norms	4.57 (2.87)	5.44 (2.68)	.344	3.90 (2.62)	5.67 (2.15)	.129
	PBC	4.25 (2.56)	6.16 (2.35)	.022	3.95 (2.83)	6.85 (2.27)	.026
	P1 (Vaccine's cost)	3.53 (2.82)	6.37 (3.34)	.007	4.30 (3.13)	6.33 (3.94)	.227
	P2 (Time and manpower required)	1.11 (5.30)	5.11 (4.27)	.015	−1.20 (5.01)	5.78 (4.38)	.005

Note: Analysis is presented separately for all farmers for which the behaviour was recorded ($N = 38$) and only for future behaviour ($N = 19$) (for the beliefs only significant results ($p < .05$) are presented).
Abbreviation: PBC, PBC, perceived behavioural control.

TABLE 3 Comparison of the intention to vaccinate and the average direct and indirect measurements of attitude, norms and PBC, between farmers who answered the questionnaire before and during/after the LSD epidemic in 2019

		LSD epidemic in 2019		
		Before ($N = 57$)	During/after ($N = 33$)	
		Mean (SD)	Mean (SD)	T-test, *p*
Intention		3.35 (1.47)	4.33 (0.82)	<0.001
Direct	Attitude	3.44 (1.17)	2.98 (1.23)	0.085
	Norms	3.41 (1.32)	3.67 (1.06)	0.348
	PBC	3.89 (1.50)	4.36 (1.03)	0.114
Indirect	Attitude	16.70 (4.34)	16.46 (4.39)	0.806
	A3 (The vaccine will not cause adverse reactions)	14.07 (5.27)	11.21 (4.99)	0.013
	Norms	3.32 (2.63)	4.70 (2.95)	0.024
	N1 (Hachaklait)	3.61 (5.01)	5.97 (4.30)	0.026
	N3 (Veterinary services)	5.11 (3.92)	6.82 (3.59)	0.043
	PBC	4.88 (2.63)	4.87 (2.18)	0.987

Abbreviations: LSD, lumpy skin disease, PBC, perceived behavioural control.

influencing compliance deterioration is the reduction of the farmers' perceived social pressures to vaccinate. This social pressure was attributed to both private ('Hachklait') and governmental (the Israeli veterinary services) veterinary organizations. Together with availability of manpower for vaccination and price considerations, these are the major causes of reduction in vaccination compliance. These findings open an opportunity for interventions to mitigate the compliance deterioration of vaccination for epidemic diseases.

Vaccination compliance is a well-studied issue in human medicine (Betsch et al., 2018; Brewer et al., 2017) and recently is being studied also in veterinary medicine (Elbres et al., 2010; Eschle et al., 2020; Gehrig et al., 2019). Like other studies in which the TPB was used to explain and predict behaviour, we found that the three main constructs – attitude, subjective norms and PBC – predicted the intention to vaccinate (Agarwal, 2014; Schmid et al., 2017).

Both in human medicine studies (with a particular focus on Influenza vaccination) and veterinary medicine studies (e.g. vaccination against Bluetongue disease in cattle), the intention and/or behaviour to vaccinate are significantly associated with the attitude of the decision maker towards vaccination (Schmid et al., 2017; Sok et al., 2016).

TABLE 4 The factors associated with the intention to vaccinate against lumpy skin disease (LSD)

Background factor/Question	Estimate	SE	*p*
A1 (The vaccine economically beneficial)	0.057	0.014	<0.001
N5 (Private vet)	0.116	0.022	<0.001
Area – North	0.670	0.374	.077
Area – South	0.914	0.374	.017
Before the LSD outbreak	−0.685	0.207	.001

Note: Results of a multivariable linear regression model in 90 RAA questionnaires filled by Israeli dairy farmers.

Similar to the current study, these studies show a significant association of social pressures with intention. The most important normative referent is the physician/veterinarian. In the current study, we further show that the normative referents can be either governmental (Israeli veterinary services) or private veterinarians ('Hachaklait'). At the level of attitudinal beliefs, there are also similarities. In the study of Sok et al. (2015) who surveyed Dutch farmers, it was indicated that the most influential attitudinal beliefs relate to being insured both economically and psychologically from the disease consequences. In our study, the most influential beliefs were related to the economical benefit of the vaccine, reducing the severity of clinical signs, receiving money from the insurance company, having peace of mind and reducing the number of disease cases. However, as opposed to Sok et al. (2018), we have not found a significant association of intention to vaccinate with the relative risk attitude, or the yearly milk quota (another measure of the size of the herd). This might stem from the low variance among the Israeli dairy farmers and herds which did not enable enough power for such a comparison.

The main novel contribution of the current study is to the understanding of vaccination compliance deterioration as time elapses from an epidemic. Given the consequences of LSD epidemics, one would expect that previous experiences with the disease should have been associated with higher compliance. Surprisingly, we did not find such direct association. However, we did find lower vaccination compliance in the Centre of Israel, which was the least affected area during previous LSD epidemics. This may indicate again on the influence of the existing norms in the area on intention to vaccinate. When comparing of farmers' direct and indirect measurements of attitude, subjective norms and PBC before and after the epidemic of 2019, we found both higher perceived social pressure to vaccinate and higher intention to vaccinate, after the 2019 epidemic compared to before. Interpretation of this result should be performed cautiously, as the situation right after the epidemic in 2019 is not the exact situation in 2016. In 2016, vaccination became voluntary 3 years after the last epidemic. We also lack the exact picture of the actual reduction in perceived social pressures to vaccinate after the epidemic.

According to the TPB, the PBC construct moderates the interaction between the intention and the behaviour (Armitage & Conner, 2001). This is supported by our results, as we found that among farmers who intended to vaccinate, PBC was the main differentiating factor between farmers who vaccinated and those who eventually did not vaccinate. The 50% reduction that we found from intention to behaviour is indeed within the range described before for different behaviours (Sheeran, 2002) but high compared to human vaccination studies (Brewer et al., 2011).

Another important finding in our study is that past vaccination is a reliable and strong predictor of future vaccination. The multivariable analysis on the data of the 566 dairy farms insured by the 'Hachaklait' organization indicates that farmers who vaccinated their herd both in 2017 and 2018 were about 120 times more likely to vaccinate also in 2019 than a farmer with no history of vaccination. This finding was independent of any other demographical characteristics. However, this past behaviour itself can be the result of certain attitudinal, normative and control beliefs (Brewer et al., 2017). This finding implies that most of the effort to increase vaccine compliance should be focused on farmers who withdrew from vaccination or never vaccinated their herd against the disease.

The current study suffers from several limitations. One limitation is the small sample size of farmers who answered the TPB questionnaire. These questionnaires were a subset of a larger study in which the behaviour of farmers was studied to four other livestock diseases. Ideally, each farmer would have been surveyed on all five diseases. However, since that would have made the questionnaire exceptionally long, we preferred to ask each farmer randomly about one disease. Another possible limitation is that the study does not follow the same persons over time and thus does not show directly the personal change of farmers' beliefs. Rather, we interviewed different farmers at different times and compared the answers. It should be noted, however, that interviewing the same persons at different times may create response biases due to the gained experience by the farmers who repeatedly answer the same questionnaires (Wetzel et al., 2016). It would be, however, interesting to perform similar studies using a repeated questioning methodology as well and to compare the results with the results of the current study.

5 | CONCLUSIONS

The results of our study suggest that future strategies to mitigate vaccination compliance deterioration should be focused on encouraging veterinary organizations (both private and governmental) to continue and exert social pressures on the farmers to vaccinate. The success of such a strategy probably depends on the existing trust between the farmers and the veterinarians and the robustness of the veterinary infrastructure. Veterinarians can also be the main agents to educate farmers regarding the vaccine and the disease. We also suggest that identifying and helping farmers who have difficulties, either in manpower allocation or vaccine funding, may increase vaccination compliance. Such strategies should be examined in the future and their effectiveness should be critically evaluated. It is also of interest to examine the change in beliefs of the veterinarians themselves as time elapses from an epidemic of LSD as well as of other infectious diseases.

These will help to maintain high vaccination compliance along time and prevent the recurrence epidemics.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

The study was reviewed and approved by the committee for studies involving humans, of the faculty of agriculture, food and environment at the Hebrew university of Jerusalem.

DATA AVAILABILITY STATEMENT

Script and data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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